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COSMICAL EVOLUTION

A NEW THEORY
OF
THE MECHANISM OF NATURE

BY
EVAN McLENNAN.

> Thus, there followed one another, five provisional theories of the Solar System, before the sixth and absolutely true theory was reached. In which five provisional theories, each for a time held as final, we may trace both the tendency men have to leap from scanty data to wide generalizations, that are either untrue or but partially true; and the necessity there is for these transitional generalizations as steps to the final one.
>
> . . . .
>
> To the true reformer no institution is sacred, no belief above criticism. Everything shall conform itself to equity and reason; nothing shall be saved by its prestige.—HERBERT SPENCER.

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PREFACE.

> What are we in this so-called nineteenth century doing in our laboratories and our libraries? Too many of us are content to acquire simply what others have observed and discovered, with an eye directed mainly to medals, certificates, diplomas and other honors recognized as the fruits of "passing."
>
> —*Prof. William Crookes.*

The reader will find in the following pages a brief discussion of a system of cosmical evolution, the general conception of which, so far as the author is aware, has at least the merit of originality.

Although the title of the work implies consideration of the entire system of natural phenomena, only about half of that system is investigated. The actual mechanism of what may be termed the molar or macrocosmic phenomena of nature, is here discussed,and, it is thought, clearly, though briefly, explained; and the system is consecutively carried down, step by step, to the threshold of the molecular or microcosmic phenomena. But, for various reasons, the discussion of these latter phenomena themselves, involving the actual mechanism of heat, light, sound, gravitation, magnetism, and even vital and mental action, has not been undertaken in the present work, with the slight exception of one or two facts selected from this domain, which are given in Part I.

In the discussion of a general system of evolution, the professional student of nature may probably expect to meet with the most profound and intricate mathematical conceptions. But to such expectations the perusal of the following pages will bring only disappointment. Instead of magnificent formulas and highly complex processes of reasoning, the most elementary mathematical facts and the simplest physical conceptions are employed. Although most of the conceptions are, it is believed, entirely new, yet their simplicity is such that no greatly involved processes are necessary in their presentation. It is true that the present theory, as well as the new one, is also discussed. But only the elementary conceptions of that theory are investigated, and even though it had been necessary to employ higher mathematical language as a means or scaffolding for the investigation of these, perhaps it would not, after all, be improper to apply in this case the rule which Prof. Marshall applied in the discussion of economic science: "When a man has cleared up his mind about a difficult economic question by mathematical reasoning he generally finds it best to throw aside his mathematics and express what he has to say in language that is understanded of the people." * At least it has been the constant endeavor in the present work to reduce every expression to the simplest possible terms which would convey its essential elements before submitting it to the reader.

But if the new conceptions here presented are so simple and yet so important, how, it may be asked, could they possibly have escaped the researches of the many distinguished scientists who are now, and have been for many years past, so diligently engaged in gleaning discoveries and facts in every field of nature?

* *Academy*, June, 1881.

This is, indeed, a grave question, but perhaps it admits of an answer equally grave. There appear to be various circumstances which would permit very simple and yet very important facts to be overlooked by the present methods of scientific inquiry. Among these, the following may here be mentioned.

First, the great majority, if not indeed all, of the scientists of to-day appear to accept, without question, the general conceptions of physical science which have been formulated about a hundred years ago. These conceptions seem to be generally regarded as already demonstrated, and therefore as requiring no further examination or attention. The greatness of their original expositors serves as a proof of their correctness; and such conceptions as the universal distribution of heat and light and the force of gravitation in accordance with the law of inverse squares are not only no longer regarded as open to debate, but, with many persons, the questioning of such "laws" is regarded as the surest proof that the questioner is himself in error. These things are so commonplace, so familiar, and apparently so indisputable to all scientific minds that they no longer receive scarcely any thought—which quite possibly may be, in the recent words of the Duke of Argyll, "a signal illustration of the power of neglected elements in reasoning—of the familiar becoming the practically unknown, because it is the unconsidered."*

Second, there appears to be at the present time no general physicist. In these days of "mental high pressure," almost every scientist is a specialist; that is, his investigations are limited to one particular branch or subject, to which his whole time and energy are devoted. In observational astronomy, for instance, there are investigators whose labors are spent almost entirely upon some one or other of the following subjects: The Sun, the Moon, the planets, the comets, the cometary orbits, the double stars, the nebulæ, photometry, spectroscopy, the computation of the elements of planetary orbits, etc. This specialized work undoubtedly has its advantages; but it may also have its disadvantages And among the latter quite possibly may be that the general connection of scientific knowledge is, to a great extent, lost sight of. The bearing and effect of the work done in one department with respect to that done in another, or in all, does not, perhaps, receive the attention which it should. The architect and overseers may possibly have become workers; and the army of workers, perhaps, are busy at mere "brick-making."*

---

*Nature, XLI, 296.

And third, it seems highly probable that the human race is, at the present time, only in its infancy. To the intelligent student of human progress, this would

*This expression is borrowed from the Annual Address of Dr. William Harkness, President of the Philosophical Society of Washington, delivered on December 10, 1887. Upon this subject Dr. Harkness expresses himself as follows: "The great increase of ephemeral scientific literature has led multitudes of educated people to believe that such records represent actual progress. The multiplication of bricks facilitates the building of houses, but does not necessarily improve architecture. Similarly, the multiplication of minor investigations improves our knowledge of details, but rarely affects the great philosophic theories upon which science is founded. The importance of human actions is measured by the degree in which they affect human thought, and the only way of permanently affecting scientific thought is by modifying or extending scientific theories. The men who do that are neither numerous nor do they require weekly paragraphs to record their deeds; but their names are honored by posterity. Even in this golden age the advance of science is not steady, but is made by spasmodic leaps and bounds. Mere scientific brick-making, commonly called progress, is always the order of the day until some genius startles the world by a discovery affecting accepted theories. Then every effort is directed in the new line of thought until it is measurably worked out, and after that brick-making again resumes its place."

appear from the comparatively recent date of our savage condition, and from the tremendous strides we have made in the period since that time. No one pretends to assign the slightest reason why both our period and our progress should not be much greater in the future than in the past. Yet there are those (even among scientists) who believe that, in the thousands (perhaps millions) of years to come and the possible myriads of our probably far more intelligent posterity, no person, or number of persons, shall be able to detect the slightest flaw in the general physical conceptions which we have set up! The fact of the existence of such a belief would alone seem a sufficient evidence of our present intellectual childhood.

It needs no elaborate discussion of these considerations to show the reader that the discovery of new truths would be greatly hindered by them. In consequence of the first, there would be little attempt at discovery of new general truths because there is no apparent necessity for new general truths. The present conceptions are held to be as good as perfect; and, if perfect, they are all-sufficient, and the whole truth is already known. In consequence of the second, the discovery of a general truth would be a matter of still greater difficulty. The *special* character of the researches of each investigation would alone preclude, to a great extent, a *general* application of them. But the worst feature would be that these special researches are themselves largely directed and appraised by the accepted general conceptions; so that, if the results of these researches are found to be at variance with the standard conceptions, the former would evidently at once be regarded as doubtful—as possibly vitiated by some unaccountable error. Some researches lead to results that can not be disposed of in this way; such as the equable temperature of the Earth's surface at varying distances from the Sun, the greater theoretic solar heat at the North Pole than at a point at the Equator during our summer season, the greater tidal wave actually due to the Sun's influence upon large isolated bodies of water, etc. These results of calculation or observation can not be disputed, and, being inexplicable by the standard theories of these phenomena, serve to excite astonishment for a time and are then forgotten. But many of the results obtainable from complicated researches depend upon such delicate processes as to readily admit of misinterpretation in comparison with possibly erroneous criteria by which they may be judged. How much of this misinterpretation is really taking place at the present time future developments may show more fully.

It must not be understood from this that the labors of scientific men are sought to be disparaged. Nothing could be further from the present purpose. They always do only what they conscientiously believe to be for the highest interests of science. As human beings they are liable to err; but if they err, they do so unconsciously; and they are quick to admit and to rectify any error into which they may have fallen when once they are aware of it. Small indeed are their failings in comparison to the benefits they have conferred. It is to their untiring labors in all ages and climes that about all of our civilization and prosperity is due. They have always been at the fore-front of our progress, and in all probability will continue to be as long as our race endures.

The indebtedness of the present work to previous researches by other inquirers will be sufficiently obvious in its perusal. The original theory here advanced has not indeed received any direct indorsement; but it has been indirectly hinted at as far back as the time of Newton. And the scientists of to-day appear to be running down the facts so closely that, were it not apparently for the drawbacks named, it would be merely a question of time, and probably a very short time too, when all of the new views here presented would be forced upon the attention of scientists by their own investigations. Much of the results of these investigations are quoted directly in the following pages, and the reader is left to judge for himself the value of this portion as evidence confirmatory of the new theory.

This work is not addressed to any special class or profession, but to all who can read and reason; and who are willing to devote a small portion of their time and thoughts to an attempt at understanding the really wonderful and important phenomena of nature which they see around them but heed not, and to the discussion of problems of origin and destiny profoundly affecting our world and our race. Such phenomena and problems are neither few nor uncommon. But strangely enough, nearly all of these highly important phenomena, which are almost of daily occurrence before our eyes, are, even in this boasted golden age of discovery, utterly inexplicable by all of our science and philosophy.

From what cause and how did this world of ours come into existence? How did it come to circulate around the Sun in its present path and at its present rate? What are the changes which have taken place upon it, and by how many races of beings like ourselves has it been inhabited, in the past? What causes bodies to fall towards its center? Why does the magnetic needle point invariably towards the north upon the greater portion of its surface? What is the nature of the aurora and the electricity manifested in its atmosphere? Why does its temperature increase at a regular rate from its surface towards its center, and what is the physical condition of its internal regions? What causes the tides upon its ocean surface? How did it happen that plants and animals of temperate latitudes once flourished far within its Polar Circles, and that subsequently almost its entire surface was encrusted with a thick sheet of ice? What caused the extremely favorable conditions for vegetable growth denoted by the coal deposits of its Carboniferous Age? What is the significance of the changes which are now taking place upon it—the earthquakes and earth-tremors, the geysers, the volcanic eruptions, and the displacements of the vertical and of terrestrial latitudes? What changes are yet to take place upon it, and what is eventually to become of it?

How came the Sun, the Moon, the planets, and the innumerable stars, into their assigned paths or positions? What is the nature and the significance of the sunspots, the solar corona and the zodiacal light? and what is the connection of these strange phenomena with the atmospheric conditions and changes upon the Earth? What are the comets which, with their mysterious trains, sweep around the Sun, and the meteorites which, as occasional bearers of strange organic remains, fall from the depths of space upon our world; and whence came they and why? What is the nature of the magnificent Saturnian Ring, and how is its equilibrium maintained? And, finally, what are the temporary stars which suddenly blaze forth in the firmament, and then gradually die away, the variable stars, which increase and decrease in luster in regular periods, and the gauzy nebular forms?

These are some of the subjects discussed in this work, and surely they are worthy of a small portion of our time and attention. "In the midst of this universe of seething movements is our home. The mind, uplifted in the effort to contemplate them and grasp their method, grows giddy and impotent. How sublime these activities! To what a numerous and lofty companionship does our little planet belong! Hard it seems to be imprisoned here while the realm of the universe tempts us to its exploration. How can a human soul content itself to roll and whirl through space during its mortal days, and eat and sleep and trifle, like rats in a ship at sea, without wondering where we are and whither we are bound."[*] To what nobler subjects than these can the mind revert in its leisure moments from the more pressing affairs of life? And how sad to think that so many intelligent beings are so swallowed up in the whirl of worldly affairs that they pass their whole lives upon our little Earth-ship, sailing in the ocean of Space, without a single thought of the ship as a whole, of the noble machinery which propels and steers it, of its port, of its destination, and of the almost infinitude of grander vessels and curious minor craft that keep us company!

But the present work appeals not alone to these considerations. It claims to present new results of the highest importance even in our worldly affairs. All the secrets imparted by Nature to her ardent devotees will undoubtedly become Aladdin Lamps of convenience and usefulness some day. But one or two facts presented in the following pages appear to become useful at once. These facts, which connect the actual amounts of atmospheric precipitation, pressure, etc., upon our world, as effects of factors which are readily calculable for any future time, though their application is yet only in its initial stages, would alone repay, it seems, the perusal of the entire volume.

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[*] Alexander Winchell, *World-Life*, p. 142.

Considering the nature and scope of the subject, it is too much to expect that this first discussion of it (on the basis here employed) can be wholly free from defects. The utmost pains have, indeed, been taken to guard against statements which might at any time turn out to be inaccurate. But, judging from the experience of the past, it is really beyond the power of one man, or even of one generation of men, to command perfect accuracy in a system so new and so vast, and with the partly incorrect and very insufficient data that are available at the present time. It is confidently believed, however, that enough new truths are scattered throughout the work to more than compensate for the possible errors which it may contain; and also that these truths, however unpolished and crude they may now appear, will yet obtain important places in the edifice of human knowledge.

The author is greatly indebted to several scientific men for much valuable information which he could not conveniently obtain otherwise, and which, although they very likely could ill spare the time, they always promptly and cheerfully forwarded, however often similar favors had been asked before. To Gen. W. B. Hazen and Lieut. A. W. Greely, Chief Signal Officers, U. S. A.; Prof. S. P. Langley, of Allegheny Observatory, and Mr. G. W. Hill, of the *Nautical Almanac* office, the author is especially under obligations for such aid.

BROOKLYN, Iowa;
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COSMICAL EVOLUTION.

INTRODUCTION.

If it happens to any of us as to
A man who looks at glass,
On it may stay his eye,
Or, if he pleases, through it pass,
And then the heavens espy;
are not those heavens which are beyond the immediate objects of our observation coloured by our prejudices, prepossessions, emotions, or imagination, as often as they are defined by any profound insight into the depths of Nature's laws ?—*Prof. W. H. Flower.*

1. *The Riddle of the Universe.*—The great, silent heaven in its ceaseless round of Sun, Moon, and stars, must early have engaged man's profoundest attention. When his mind emerged out of the primordial darkness, and the barbarian struggle for existence had lulled; when his daily wants were supplied, and he began to have leisure from the pitiless toils of capturing prey or destroying his enemies—the mysterious, all-surrounding expanse, and the restless objects with which it was peopled, could not but excite his attention and wonder. And probably the earliest flights of his fancy and exercise of his reason were directed to solve the grand riddle of his being and his environment.

2. *Pocket-Filling Ambition Versus the Study of Nature.*—There is a charm for man in the study of Nature. It elevates his soul to real greatness. It frees his mind from stormy life, and thrills him with the purest joy. It leads him up to truth, and opens his

view both to the cradle of his existence and to his goal. Worldly life is a real exile for the soul—a confinement to the shallow joys and appearances of the present—a separation from the true joys and blessings which Mother Nature, ever young, bestows upon her children who cherish her. The worldy soul, sometimes returning to itself in hours of solitude, feels the emptiness and vanity of its chiefest aims, and is homesick. The many, content to conform themselves to their circumstances, sink in the devouring gulf of custom, die, and are forgotten. A few contrive to escape. It is no easy thing; but, with indomitable energy and perseverance, they find their way to Nature whom they love, and who confers upon them her gracious bounties and reveals the secrets of her bosom regarding the true aims and happiness of mankind. These never die or are forgotten; or they perish only with the human race. Their labors and their memories are preserved and cherished, as it is right they should be. For sad indeed would be the condition of mankind to-day but for these daring and devoted few. The sun of civilization would not yet have risen upon the world, and all people would be in the cimmerian darkness of the lowest barbarism.

3. *Nature of Man's Earliest Conceptions of the Heavens.*—The earliest conceptions of man, as handed down to us in the legends of antiquity, may seem to us crude and childish. But nevertheless they have been of no small value. They were the first stepping-stones to the temple of knowledge, and without them, or others equally as crude, the grander conceptions of Kant and Laplace could never exist. The ideas of the origin and mechanism of the universe which these legends convey are extremely various; for every isolated race and tribe had a legend of its own. Each

bears the imprint of the peculiar conditions of its native locality; and each attests that man's first attitude to the forces of nature was that of wonder, mingled with fear. His sole standard of things and actions was himself and his life. Everything that moved he conceived to be animated, and the movement directed by a personal will for some personal end. In countless different ways was the personification expressed. There was a ceaseless battle between the darkness and the light. In the raging tempest, when light and darkness alternately prevailed, the heroes of the spirit-land waged the war of their still unsettled blood-feuds. The forked lightning serpent was the foe of the thunder-bird. To the Aryans, a pastoral people, the Sun was the bull of majesty; the white clouds driven by the children of the morning to their pastures in the blue fields of the sky, were cows from whose swelling udders dropped the milk of heaven—the rain. In the dark clouds dwelt the mountain robber Vritra, the thief-dragon, who lured away the herds, until Indra, the sun-god, smote him with his shafts and set free the imprisoned cows. In Latin guise, Indra and Vritra became Hercules and Cacus; in Greek myth, Apollo and Python; and in the Scandinavian legend, the grim and fearful ogres sailing swiftly in their cloud-ships and Odin and his phantom crew. The rainbow was a demon coming down to drink when the rain fell; or the Heaven-ladder or bridge along which the souls of the blest are led by angels into Paradise. The tides are the beatings of the ocean's heart. Volcanoes were the dwelling places of angry demons. And there were Spirits of the mountains, of the woods, of the winds, of the waterfalls.

4. Various Legends of Creation.—The more general conceptions were of a similar character. In the Babylonian legend, handed down by Berosus, the goddess of Nature, mother of all, is cut in twain by Belus, chief of the gods, one-half becoming the sky and the other the Earth. Belus, unable to bear the light which he thus created, cut off his own head; and from his blood, mingled with the dust of the earth, arose the race of men.

In the Hindu legend, from the laws of Manu, Brahma dispelled the original darkness and gloom and created the waters. In the waters he placed a seed. The seed produced a golden egg of a thousand brilliant beams; and in this egg Brahma gave birth to himself. He split the egg in halves, one becoming heaven and the other Earth. He then created gods and wise men, who in turn created demons, animals, clouds, mountains, and rivers.

The Greek legend of the Theogony is that in the beginning was Chaos. From Chaos came Gaia, the Earth, and Tartarus dreadful and dark below. Then appeared beautiful Eros. The Earth gave birth to Uranus, the starry heaven, and to the mountains and the sea. Then Gaia and Uranus married, and from them sprang demigods and men.

The Scandinavians conceived a yawning gulf south of which was a region of flame, and to the north an abode ice-cold and dark. Torrents of venom flowed from the north into the void, filling it with ice, but the flames of the south melted it and formed water. Out of the water arose Ymir and his wicked family of frost-giants. Ymir was slain by Odin, Vili, and Ve, and out of his flesh they formed the earth, from his blood the seas and waters, from his bones the mountains, from his hair the trees, from his skull the heavens, from his brains the floating clouds, and from his eyebrows a wall around the earth to guard them from the giant sons of Ymir.

5. *Primitive Astronomical Ideas of the Past.*—Descending from the universe as a whole, let us glance at man's earliest interpretations of its component parts. The Hindu conceived the Earth to be supported by animals standing one upon another, four elephants being the lowermost, their legs reaching all the way down. The over-arching sky was firm and solid like a hammered plate and rested upon the borders of the flat Earth. It had windows in it to let the rain through and gates through which angels descended, or through which prophets saw into the mysteries of the beyond, and outside of which lived other people.* The Sun, Moon and stars were father, mother and children, or heroes translated without seeing death. Their movements are prompted by love, jealousy or revenge; sometimes borne across the heavens on the backs of ancestors, swimming again to the east through the ocean, or transported across by fishes waiting to receive them. The stars were men who climbed to the top of a tree, and were left in the branches by the trunk being cut away. The Milky Way was the place where the two halves of the sky were joined together. It was, also, like the rainbow, the ladder or the bridge whereby the departed pass from Earth to Heaven; the Red man's road of the dead to the Sun; the Roman path of, or to, the gods. The Moon was chased by monster dogs or wolves that bit and wounded her until her blood hid her from the view; and, to render her assistance, a fearful noise was made to frighten the monsters away. Or she was continually hacked and maimed by the Sun for loving the morning

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*The Polynesian term for a stranger is "papalangi" or heaven-burster.

star. Eclipses were caused by great dragons trying to devour the Sun and Moon. The Chinese and the nations of India beat brass kettles, and the Peruvians beat their dogs to make the monsters give up their prey. Meteors were the souls of the departed taking their flight from Earth. And the Northern Lights were the shades of ancestors in spirit dance; the brighter the flashes of the aurora the greater the merriment.

6. *Primitive Astronomical Ideas of the Present.* —This is the childhood of the intellect;* and it is by no means confined to any single age. Indeed very gross conceptions of the heavens are entertained by our own contemporaries. The Namaquas, a branch of the Hottentots, regard the Sun as a lump of "clear fat," which seamen attract to themselves by enchantment during the night and spurn in the morning because they have no further use for it. The Moon is a man riding an ass, and wanes because he puts his hand up to his head when he has a headache. According to the Patagonians, two men quarreled over the parentage of a child; as a result of which it was cut in two, one man taking the upper half and immediately flinging it in the sky, thus forming the Sun. The other sullenly let his lie on the ground; but seeing the glory of his rival's share, he waited till the Sun went down and then flung his part in the sky also, thus forming the Moon, whose paleness is owing to the blood having oozed out as it lay on the Earth.

Nor are the savages entirely alone, perhaps, in the anthropomorphism of astronomical conceptions.* While the most of us have outgrown such gross legends as that of the Man in the Moon, yet, to quote the words of Prof. Flower at the third Newcastle meeting of the British Association, "It is impossible to be blind to the fact that we who are engaged with the investigation of those subjects which are commonly accepted as belonging to the domains of physical science are unfortunately not always, by virtue of being so occupied, possessed of that most precious of gifts, 'a right judgment in all things.'" And again, "are not those heavens which are beyond the immediate objects of our observation colored by our prejudices, prepossessions, emotions or imagination as often as they are defined by Nature's laws?"

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* For these legends more in detail and many others the reader may consult Edward Clodd's *Childhood of the World*, *Childhood of Religions*, *Birth and Growth of Myth*, and Fritz Schultze's *Fetichism*; wherein many other authorities are cited.

7. *The Dawn of Astronomical Science.*—Although the oldest of the sciences, astronomy has been pretty much a concatenation of illusions quite similar to these from the earliest observations of the Chaldean priests down to the time of Copernicus, or the beginning of the sixteenth century. This specially applies, however, to physical astronomy, with which this volume throughout will be chiefly concerned.

In the earliest times the Earth was regarded as fixed, and the heavens as revolving around it every twenty-four hours. Pythagoras and his disciples (about 500 B. C.) are said to have conceived the true heliocentric theory of the planetary world. But if this doctrine was taught at that time, it was soon forgotten or ignored. Great geometrical and mathematical discoveries in astronomy were made by Hipparchus of Bithnia (about 160–125 B. C.) and by Ptolemy of Alexandria (about 139 A. D.); and the geocentric theory of Thales (also accepted by all ancient philosophers of eminence, including Aristotle and Plato) was invested with these discoveries and built by Ptolemy into the theory known as the Ptolemaic System, or Almagest of the Arabians.

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* "Looked at from this point of view, we can not refuse to regard them (the 'willow-leaves' of the Sun's surface) as *organisms* of some amazing and peculiar kind, and though it would be too daring to speak of such organization as partaking of the nature of life, yet we know that vital action is competent to develop at once, heat, light and electricity."—*Sir John Herschel*, quoted by Prof. Langley in the *Century Magazine*, Vol. VI, 717. The "willow-leaves" are about 1,000 miles long by about 200 miles broad.

8. *The Almagest, or Ptolemaic System.*—A glance at this venerable and at one time universally approved thought-structure may be instructive. The belief that the Earth was the center of the universe Ptolemy supported by the observed relations of the primary elements. Thus earth, the most stable of the elements, held the lowest place and supported water, the second in order. Above water was placed air, then fire, then ether; the latter being supposed to extend indefinitely above all. In or above the ether were successive, concentric zones or heavens, each heaven containing an immense crystalline shell or sphere to which was attached a heavenly body, and which revolved around the Earth carrying the body with it. The smallest sphere or crystalline surrounded the Earth and its elements, and carried the Moon. The next in their order from the Earth carried Mercury, Venus, the Sun, Mars, Jupiter, Saturn, and the fized stars; eight in all. Later astronomers added a ninth, the motion of which caused the precession of the equinoxes, and a tenth, or *primum mobile*, revolving from east to west in twenty-four hours, and imparting motion to all the others. As geometrical observations increased in accuracy, it was found that the motions of the heavenly bodies were apparently not uniform. Sometimes a planet

moved slowly and at other times comparatively fast. This was explained by supposing that the Earth was not at the center of the sphere of that planet but more to one side, and that the planet, when carried past that side, would seem to move more rapidly owing to its nearness, and, when on the other side, more slowly owing to its distance. The path thus described by the planet with respect to the Earth was called an *eccentric*. At other times a planet seemed to stand still, move backwards, and then rapidly forwards. This was really owing to the different positions of the planet and the Earth, and their different velocities, *around the Sun*. But the Ptolemaic astronomers attributed it to a movement of the planet, not directly with the crystalline, but in a smaller secondary orbit, the center of which was a fixed point in the crystalline; so that, when the planet was in the outside half of the secondary orbit, it moved rapidly forwards, and when in the inside half, it moved backwards. The path of the planet in this secondary orbit was called an *epicycle*.

This theory of eccentrics and epicycles, upon still further investigation, was seen to be still further defective, until finally it was found necessary to pile epicycle upon epicycle, and patch explanation upon explanation so much that Alfonso X., of Castile, to whom it was being taught, was led to exclaim that "if the Deity were now to reconstruct the world, he (Alfonso) could give him a few useful hints." Yet this theory commanded the approval of the best intellects of the world for about *two thousand years*, and was replaced only in the beginning of the sixteenth century by the Copernican System.

9. *The Copernican System.*—This system, which is the one now held, regards the Sun as at rest in the center,

and the Earth and the planets as moving around it in ellipses. The general idea of this system was very probably first promulgated by Pythagoras, as already stated. But to Copernicus belongs the honor of its revival after the lapse of so many centuries. He attempted to explain for the first time the variations of the seasons, the precession of the equinoxes, and the stations and retrogradations of the planets, according to this system. But his knowledge of mathematics and mechanics was not great, and, to account for apparent irregularities, he was obliged to introduce a system of epicycles similar to that of Ptolemy.

Subsequent philosophers, however, sought to explain the motions of the planets by a theory of vortical motion. This theory, probably suggested to the mind by the familiar phenomena of whirl-winds and whirlpools, was in existence ages before this time, but the Copernican System awoke it into new life and energy.

Kepler (1571–1630) conceived the Sun to be a magnet, the *immaterial substance* of which was sent forth radially in all directions. These radiations rotated with the Sun, thus constituting a universal vortex, the motion of which carried with it the planets. The Sun's surface was attractive and its center was repulsive, and these two forces (which Empedocles, about 450 B. C., designated "love" and "hate") was everwhere in equilibrium, so that a planet had no tendency to recede from, or approach towards, the Sun. The departure of the planetary paths from the circular form was explained by supposing each planet to have an attractive and a repulsive side, which are alternately turned towards the Sun. The supply of solar emanations and their motion were constantly maintained by the Creator, or by a spirit specially designated for that employment.

By means of the observations of the great Tycho Brahé (1546-1601), to whom also he was indebted for valuable counsel, Kepler discovered his three famous laws. He also affirmed the essential inertia of matter (Galileo's first law of motion); gave a complete theory of solar eclipses; and calculated the exact epochs of the transit of Venus and Mercury across the Sun's disc.

To this same epoch also belongs the honor of producing the brilliant genius of Galileo (1564–1642). To this great Italian we owe the discovery of the three laws of motion, the law of falling bodies, and the isochronism of the pendulum. He also, with a telescope of his own invention, discovered the inequalities of the Moon's surface and the reflected nature of her light, the four satellites of Jupiter, the ring of Saturn, and the movable spots on the Sun's surface, from which he inferred the rotation of that body. For advocating the Copernican System and for promulgating discoveries antagonistic to the prevailing creed, he was, at the age of seventy, incarcerated in the Inquisition, and, after a long and painful trial, forced to retract the sublime truths which he had discovered and taught.

10. *The Vortical Theory.*—By far the ablest advocate and expositor of the Vortical Theory was the Italian philosopher, Des Cartes (1596-1650). He assumed that infinite space is filled with infinite matter, which was originally chaotic and formless. In the beginning God created particles of nearly uniform size, each of which had an axial rotation. Groups of such also revolved about distant centres. Mutual friction reduced the particles to various sizes, the smallest of which was called the "first element," and the larger the "second element." Vortices would arise in the mass owing to some groups of revolving

particles being more powerful and energetic and subduing into harmonious movement with themselves contiguous minor groups. As the vortical motion increased, the "second element" would remove from the center, the larger and more massive particles to the greater distance. But the "first element," having but little mass, and consequently but little momentum, would chiefly fall to the center, and there aggregate into a sun. This sun rotated rapidly, and sent out emanations of its element upon the plane of its equator; these emanations passing between the particles of the second element and carrying them forward; the nearest the most rapidly, because they had the least mass.

Some of the minor vortices subdued by the solar vortex, while they moved around with the latter, would yet maintain their own vortical movement, at the center of which would collect some of the first element, and thus give rise to planets. Other vortices subdued by the planetary vortices would in a similar manner account for the satellites. But some vortices would escape from the influence of the solar vortex, and these last would become comets.

This really absurd theory was so ingeniously constructed and so elaborately finished in detail by the great intellect of Des Cartes that there was little doubt of its correctness; and, indeed, it was the most plausible theory of cosmical mechanism at that time. It was advocated by many eminent scientists, and, for a time, maintained its ground upon the continent against the theory of gravitation.

The German philosopher and mathematician, Leibnitz, accepted the general cosmical conceptions of Des Cartes, but he modified them so far as to recognize the necessity of a tangential force and a central attractive force to guide the motions of the planets.

Leibnitz also conceived the germs of geology. In his *Protogoea* he plainly states his belief that our world was primitively in a molten state; and that, in cooling, it formed a crust which, upon continued refrigeration, was crumpled up into mountain ranges and depressed into ocean basins. The action of water upon the plutonic rocks ground them down into sediment, which, collecting into strata, was again solidified. Thus he combined aqueous and igneous action as in modern geology; although long subsequent scientists, less wise, wrangled long and bitterly in favor of either.

In various forms the vortical theory was promulgated and defended by many other philosophers and scientists. But it soon began to lose ground. When fairly contrasted with the new theory of gravitation, its flimsiness and absurdities became plainly apparent. Yet, in the words of Chambers' Encyclopedia, its author "is not to be laughed at; mistakes more ridiculous than his are gravely propounded at the present day."

11. *The Theory of Gravitation.*—Sir Isaac Newton, the illustrious English philosopher and mathematician, and founder of the theory of gravitation, was born in 1642, the same year in which Galileo died a prisoner in the Inquisition. It is said that in 1665 the law of universal gravitation was suggested to his mind by the fall of an apple in his garden. Might not, he reasoned, the same force that caused the apple to fall, extend outwards to the Moon, and acting on that body with an energy diminished by the distance, pull it continually from the straight path it would otherwise pursue, and so maintain it in its orbit around the Earth? No sooner did this grand conception arise in his brain than he put

it to the test of actual calculation. But the knowledge of the Earth's magnitude in those days was very imperfect, and Newton employed a value of the Earth's radius so large that, according to the law which he had conceived, the fall of a body upon the Earth's surface in each second should have been only 13.9 ft., instead of 16.1 ft., the actual fall, as previously determined by Galileo. This discrepancy was so great that he regarded the law of universal gravitation as irreconcilable with the facts, and he consequently abandoned it, until Picard, in 1670, obtained a more correct measure of the Earth. At least in the year 1684 it became known that he was in possession of the complete theory and its demonstration, and in 1687 he was persuaded by his friends to give it to the world in his famous *Principia.*

Newton's law of universal gravitation may be thus stated: Every particle of matter in the universe attracts every other particle with a force directly proportional to the mass of the attracting particle and inversely proportional to the square of the distance through which it acts. Accepting this law provisionally, Newton proceeded to its demonstration. He first showed that the attraction of the Earth is precisely the same upon another body, as if its whole mass were compressed into one atom at its center. Then, at the distance of the Earth's radius from this point, the energy of its attraction, according to the law of gravitation, is such as to cause a body to fall a distance of 16.1 feet in one second. Calling the Earth's radius 1, then the Moon's distance from the Earth's center will be about 60, and to find the energy of the Earth's attraction at the Moon, the law of gravitation gives the following proportion:

$$(60)^2 \,.\, (1)^2 = 16.1 \text{ ft.} : x\,;$$

whence x, or the pull of the Earth's attraction upon the Moon, is found to be about 0.00447 feet in each second. Knowing the Moon's period of sidereal revolution around the Earth to be about twenty-seven days, seven hours and forty-three minutes, and its distance from the Earth's center to be about 240,000 miles, then the Moon's orbital velocity would be about 0.64 mile per second; and by a simple geometrical theorem, the actual pull upon the Moon towards the center of its motion is $\sqrt{(240,000)^2 + (0.64)^2} - 240,000$, or about $8\frac{1}{8}$ miles $\times 10^{-7}$ or 0.0044 feet in each second. The actual pull and the theoretical pull are thus found to agree very closely; and the demonstration was so simple, and the accordance of theory and fact, out of the infinitude of possible discordances, was so striking and forcible that in a few years every scientist accepted it unreservedly; and it continues to be accepted without the least question or doubt down to the present day.

But this is by no means all of Newton's theory; indeed, it is only the foundation upon which that theory rests. Having found that his law of gravitation applied to the Moon, Newton next sought to apply it to the Earth itself and to the other planets. Knowing the period of the Earth's revolution around the Sun and their distance asunder, he determined as in the case of the Moon and the Earth, the attractive pull of the Sun upon the Earth in one second. This he found to be about 0.0096 feet, which was just about 315,000 times the effect which the Earth's attraction, extended to the same distance, would be able to accomplish. He concluded, therefore, that the Sun's attraction, and consequently his mass, was 315,000 times as great as the Earth's. This solar attraction would cause a body to fall at the Sun's surface a distance of about 437 feet in one second; and taking this fall, the Sun's radius, and the distance of every planet in succession, to form successive proportions similar to that employed in the case of the Earth and the Moon, he found that the pull per second of this supposed solar attraction was very nearly the same as the actual pull per second by which the planets were drawn towards the Sun and maintained in their orbits. Here was additional and apparently overwhelming evidence in support of his theory. But it was not all. The Jovian and the Saturnian systems furnished still further evidence; for it was found that the law of gravitation accounted for the motions of the satellites as fully as it did for those of the planets. Every member of the Solar System appeared to be strictly amenable to that law. And thus, from the 16.1 feet determined by Galileo to be the gravity-pull in one second at the Earth's surface, did Newton account for the motion of the Moon, the Earth, the planets, the satellites, the comets, and even the stars; for the philosopher Kant, the two Herschels, the two Struves, Argelander, Airy, and many other subsequent, as well as nearly all recent, astronomers agree that the Sun and the stars have a proper motion about distant centers, to which they are held in the same manner as the Moon is held to the Earth, or the planets to the Sun.

Thus, upon the solid basis of actual observation, with our own eyes, upon our own world, has the theory of gravitation been constructed and extended to the whole universe; to which it applies with such apparent harmony and exactness that its implicit acceptance as the essential basis of physical science by the profoundest intellects of the modern world is not at all to be wondered at.

12. *The Nebular Hypothesis.*—But after this extension and general acceptance of the theory of gravitation, there yet remained facts which were totally inexplicable. The mere orbital motions of the planets and satellites were made intelligible, but how about the planets and satellites themselves? Whence came they and in what manner? How came their orbits to lie nearly in the same general plane—that of the Sun's equator—and their motions, both of orbital revolution and axial rotation, to be in the same general direction—from west to east? And how, also, did it happen that there was an invariable relation between a planet's distance from the Sun, or primary, and its period of circulation around that body? In these adjustments, Newton could see only the finger of God. In his general scholium, he pronounces them to be the work of an intelligent and all-powerful Being.

There was one, however, to whom such an explanation was not wholly satisfactory—the great French mathematician, Laplace (1749–1827). "Might not these arrangements be an effect of the laws of motion?" he asks, "and might not the Supreme Intelligence, which Newton invoked, have caused them to depend on a more general phenomenon?" And such a phonomenon is, according to his conjecture, "that of a nebulous matter dispersed in masses throughout the immensity of the heavens." In a note at the end of his *Systeme Du Monde*, Laplace expands this general idea more into details. He commences with a universal nebulosity "so diffuse that its existence is barely imaginable." This nebulosity, aggregated into individual masses, some of which became stars and one of which became our Solar System. Through the agency of gravitat[illegible] ordial masses would concentrate and devel[illegible] ed or vortical motions of flocculi towards this nucleated mass-center giving rise to a rotation of the whole mass. Thus after a time our system consisted of a dense nucleus, or the Sun, surrounded by a vaporous atmosphere which extended "beyond the orbits of all the planets." "The atmosphere of the sun could not extend outwards indefinitely; its limit would be the point where the centrifugal force due to its movement of rotation would counterbalance gravitation. But in proportion as cooling contracted the atmosphere, and condensed at the surface of the body the molecules located in that region, the movement of rotation increased by virtue of the principle of areas." And the velocity of rotation becoming greater and greater as the solar atmosphere contracted more and more, an equatorial ring would eventually be left behind by the contracting vapor. This ring, which is supposed to have had considerable breadth, would not be of uniform density and tenacity in all its parts; and would consequently fracture and collapse into a sphere; this sphere having an orbital motion around the Sun derived from its original rotation with that body, and an axial rotation caused, and its direction determined, by the greater absolute velocity of the outer portion of the ring. This process would continue in the Sun's atmosphere until all the planets and planetoids were successively cast off and left behind. But in the meantime some of the planets, in contracting from the vaporous condition, would also acquire a rapid rotation and cast off rings of vapor which would disrupt into satellites. The present ring of Saturn for some extraordinary reason still remains unbroken, although it is supposed to be either vaporous or composed of discrete particles. The comets are entire strangers and their origin is wholly mythical.

Such is the "nebular hypothesis" of Laplace regarding the origin of the Solar System. It is, moreover, with very little modification, the view now held; but it may be stated here that recent eminent astronomers are beginning to discover insuperable difficulties in it.

13. *Astronomical Science Still in Infancy.*—Having thus rapidly passed in review the earliest astronomical ideas down to the most recent cosmological conceptions, we may here pause for a moment's reflection.

One thing this glance at our past physical views is well calculated to impress upon our minds, and that is their probable immaturity and incompleteness. The history of physical astronomy seems to be one of successive illusions, each tenaciously held for a time and given up only with reluctance. The most chimerical ideas of the heavenly bodies, their motions, their nature, and their origin, generally prevailed up to the 15th century; and it was only in the last century that any thing like true ideas of the mechanism and origin of the Solar System began to be entertained. Indeed, as already remarked in the preface, the human intellect appears to be only in its infancy. Not only is it true that the number of men who have intelligent ideas of the mechanism and laws of the universe is extremely small compared with the number of those who entertain very primitive ideas, or who entertain no ideas whatever regarding the subject, but even these intelligent ideas are but recently derived from their fallacious predecessors; and being thus recently born of error, it is really very improbable that they can be wholly free from error themselves.

The human race may be compared to a healthy and active child just beginning to exercise its reason; but with the difference that the former has no tutor. It has to answer its own inquiries and to explain its own difficulties. Consequently it makes mistakes which, however, owing to its activity, it soon discovers and replaces by others less palpable. Such seems to be our intellectual progress, from gross misconceptions to misconceptions less gross. And, if our existence and our progress is to continue, such in all probability will our intellectual progress continue to be for many years to come.

14. *Current Acceptance of Scientific Dogmas.*—With this history of our intellectual development before us—a history of successive escapes from sense-illusions—a history of man's implicit faith and confidence in the truth and perfectness of his newest conceptions of Nature, and of his subsequent discoveries that Nature is yet quite different from his newest conceptions of her—a history of the fallacies and rejection of all theories but the last one, and of the unqualified approval and acceptance of this one as a demonstrated law;—with such a history of our progress in the past, for our present guidance, it seems that we ought to have learned to be liberal towards new ideas, and to regard our present conceptions as very liable to be fallacious like all their predecesors. The fact, however, has every appearance of being the contrary. The present theory of gravitaton, *e. g.*, is regarded by nearly all scientists as a fully demonstrated fact. No recent physicist questions it, and apparently never has questioned it, but has fully accepted it upon the authority of its illustrious expounders.

Thus "owing to the temptation to accept as still sufficient any time-honored scientific dogma having respectable sponsors,"* it becomes possible that serious errors are, as they certainly have been, propagated by very intelligent men. They have little, if any, doubt of the truth and perfectness of current scientific doctrines. They do not exercise their reason at all in their investigations. Their minds are satisfied with the evidences adduced, and the magnificent talents displayed by their propounders. Their respect and reverence for these magnificent talents is so profound that it invests the doctrines and protects them from criticism as the wax protects the copper-plate. In more subordinate matters their acumen is great, and their investigation thorough; but the matters of prime importance are as if preserved under lock and key from the dangerous pryings of reason and investigation. But in science nothing should be held so sacred as to be above the strictest scrutiny with the light of reason—not once for all, but frequently; for that light becomes ever brighter and more searching as our knowledge increases with our increasing years.

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*Prof. S. P. Langley.

Now, aside from these general considerations, there are many reasons for believing that the theory of gravitation, as modified by the nebular hypothesis, is erroneous, like its predecessors. It is unquestionably a great deal nearer to the truth than any of the theories which have preceded it. But that it is still essentially defective will be made tolerably plain, it is thought, before this work is brought to a conclusion.

15. *Plan of This Work.*—Perhaps this should be the proper place to show wherein the defection of the present theory lies; and after this defection was demonstrated, then a new theory might be broached and supported by the various phenomena of nature in succession. But upon fuller consideration, it has been thought advisable that a new theory should be broached first, an

intelligent idea of its nature obtained, and an application of it made to explain a few principal phenomena, such as the sunspots, the zodiacal light, the solar corona, and the variations of atmospheric electricity, precipitation, pressure, etc. — each of which has hitherto remained inexplicable by all previous theories. After the new theory is thus placed upon a sufficiently creditable basis to admit of comparison with the present generally accepted and therefore highly respectable theory, then we may examine, not only those phenomena for which the present theory is held to account, but also those in which that theory confessedly meets with insurmountable difficulties. The accordance or discordance of each theory with each of these phenomena will be pointed out, and the reader will be left to form his own judgment as to which of the two is really the most entitled to credence. In the first place, after giving an approximate idea of the new theory, we may take a cursory glance at the two theories with respect to a single factor. The current theory involves the real or supposed entities or properties, matter, motion and force, of which the new theory employs only the first two. And a moment's preliminary comparison of the two theories in this respect may not prove wholly uninstructive.

PART I.

INTRODUCTION TO A NEW THEORY.

Men of science do not pledge themselves to creeds; they are bound by articles of no sort. There is not a single belief that it is not a bounden duty with them to hold with a light hand, and to part with it cheerfully, the moment it is proved to be contrary to any fact great or small. *Prof. Huxley.*

16. *Molecular Bonds.*—The ultimate characteristic subdivisions of a chemical element have been regarded by modern scientists as possessing a number of bonds, or "lines of affinity," by means of which they unite with other similar subdivisions to form chemical compounds. If the element is a monad, a diad, a triad, or a tetrad, the number of uniting bonds of its ultimate chemical subdivisions is supposed to be one, two, three, or four, respectively; and upon this system of bond values, or valency, of the elements, all chemical combinations, as well as the atomic weight and important electric properties, are found to depend. Not only are the ultimate elements thus united together, but the larger units into which they combine have also connecting bonds proper to themselves by which they can unite with others; and so on, from the simplest to the most complex molecule.

17. *Planetary Bonds.*—If now, with John Herapath, we take the view that "gravitation, cohesion and affinity are but the same thing under different modifications;"* if also, with Dr. Jules Guyot and others, we

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* *Annals of Philosophy*, 1816, Vol. VIII, pp. 58-9.

regard an ultimate molecule of matter as a highly complex or organized cosmos[*] (which, indeed, appears to be sufficiently demonstrated by the definite multiple periodicities exhibited by gaseous spectra); and, finally, if, with Marc Seguin, we admit that the molecules of bodies "circulate around one another so that each body, though it appears at rest, has really a certain quantity of motion, whose measure will be a function of the mass and the velocity of the molecules in motion"[†]—what real difference, except relative magnitude and complexity, can we perceive between the ultimate chemical elements, or molecules, and the ultimate cosmical elements, or heavenly bodies? and why should not the latter have connecting bonds, by means of which they remain attached together in a cosmical molecule, or system, just the name as the former do in a chemical molecule? There is really no difference, except in the respects named, between a molecule and a world. The molecule consists of a vast number of different smaller molecules, of whose properties we know little or nothing; but whose existence is demonstrated by the spectroscope in the innumerable lines of different refrangibilities into which the light from an elementary gas or vapor is analyzed. Of these different lines, each implying a distinct and different kind of motion, the spectrum of the simplest known molecule, that of hydrogen gas, exhibits no less than 1600,[‡] besides countless others which still more powerful instruments would probably reveal to us. The molecule, then, is composed of a vast number of sub-molecules, and the world or planet is composed of a vast number of molecules. And

[*] *Presse Scientifique*, 1861, III, 130.

[†] *The Edinburgh Philosophical Journal*, Oct. 1824; X, 280-2.

[‡] Nature, XXXIX, 370.

no reason, whatever, appears to be assignable why the larger aggregate of molecules should not be connected with each other by means of bonds, just the same as the smaller aggregate of molecules.

We can not say that we have no evidence of the existence of planetary bonds as we have of the molecular bonds, because there are too many phenomena in the heavens, of the nature of which we confessedly know absolutely nothing, and which may really turn out to be the very things in question. What are the tails of the comets? The astronomer frankly states that he does not know. But may not these curious appendages, which are seen to increase in magnitude as they approach the Sun, be owing to the accumulation upon the comet of the bond-substance, which extends between itself and the Sun? What are the long streamers which are seen to project to several millions of miles outwards from the eclipsed Sun? Again, the astronomer answers that he does not know. But may they not be the connecting bonds of the planets and of distant sister suns with the great central body of the Solar System? It is true that the coronal streamers are not seen extending out so far as these bodies; but owing to their extreme tenuity, is it not reasonable to suppose that they would not be visible to us individually, except in rare cases, though they might very likely be so when two or more of them would conjoin near the Sun's surface, and where extremely rare vapors from the latter might also contribute to their visibility? What is the zodiacal light, or the luminous band which, before dawn and after twilight, is observed in favored localities, to extend from the Sun outwards, apparently to the Milky Way, and almost to the utmost bounds of the starry system?

And still the astronomer can furnish but the same answer. Surely, then, before it can logically be denied that the planets have bonds by which they are attached to one another, these so-called mysterious phenomena ought to be accounted for in some other reasonable way; for they certainly seem, even at first glance, to be, in all respects, similar to just such appearances as we should expect such planetary bonds to make.

18. *The Essential Principle of the New Theory.*—Now, this is the principle, almost the sole distinguishing characteristic of the new theory, namely, that *every known heavenly body is connected with its neighboring heavenly bodies by means of real, material bonds, and that every phenomenon of the universe, without exception, is due solely to the action of bodies upon one another through, and by means of, these bonds which join them together.*

19. *The Idea of Force.*—Coming at the subject from another direction—we know that all the planets of the Solar System move in nearly circular paths round the Sun. Let us ask the astronomer what holds the planets from moving outwards from the Sun in performing these revolutions, just as a stone is projected from a revolving sling? His answer by the present theory is—The force of gravitation. But what is the force of gravitation? Is it a material existence like air, or a comet's tail? No, it is not matter of any kind, however subtile; it is immaterial. Is it a motion? No; "gravitation . . . . is not a motion, nor is it the product of any motion." Then what is it? Well, it is—just Force! It is not matter, nor motion, nor mind, nor time, nor space. It is indefinable, incomprehensible, inconceivable!

"But," exclaims the critic, "no scientific theory is final until its ultimate postulate *is* inconceivable." "For if the successively deeper interpretations of nature which constitute advancing knowledge are merely successive inclusions of special truths in general truths, and of general truths in truths still more general, it obviously follows that the most general truth, not admitting of inclusion in any other, does not admit of interpretation. Manifestly as the *most* general cognition at which we arrive can not be reduced to a *more* general one, it can not be understood. Of necessity, therefore, explanation must eventually bring us down to the inexplicable. The deepest truth which we can get at must be unaccountable".* It is indeed true that continued explanation will at length bring us down to the inexplicable; but this does not appear to be a sufficient reason why we should permit our imagination to multiply inexplicables unnecessarily. There must, of necessity, be *one* thing that is unaccountable; but it by no means follows from this that there must be *two*. Yet the ultimate nature of matter is inexplicable, and here is added to it the inexplicable entity—Force. Now matter is something which we know to exist, if we know anything; and no one has yet observed, or even *conceived* the idea of, force separate from matter. Physicists do indeed hold that one portion of matter acts upon another portion through absolutely empty space either great or small. They held first that the Sun's force of gravitation acted upon the planets through an absolute void; but they subsequently concluded that the space between the Sun and the planets was by no means a void, but contained a material fluid which they called æther. This, then, appears to dispose of the force of gravitation in any single known instance in the whole universe as acting through, or in, a space devoid of matter. When it was found necessary to abandon the idea of interplanetary vacuua, it was still held that the intermolecular spaces of the æther itself must be absolutely void, and that its molecules and atoms must be held together by means of a force acting through these absolutely void spaces. But, perhaps, when we get a little older and wiser (for which there appears to be ample room and opportunity) and learn a little more about Nature, we shall find that the intermolecular spaces are no more devoid of matter than the interplanetary spaces—that, in fact, "Nature abhors a vacuum." Dr. Balfour Stewart says: "Till we know what the ultimate nature of matter is, it will be premature to speculate as to the ultimate nature of force; though we have reason to believe that it depends upon the diffusion of highly attenuated matter throughout space."* But, really, would it not be more in accordance with the law of parsimony, which is everywhere manifested throughout nature, that we abandon the idea of force, as well as the speculations regarding it, at least until we find (what we have so far failed to do), that the attenuated matter which is regarded as the vehicle of the supposed force, and upon which it is believed to depend, is itself quite incapable of performing the functions ascribed to the supposed entity? We *know* that matter exists. We do *not* know that force exists separate from matter; and we do *not* know that matter is incapable of performing all the functions ascribed to force, because we do not know the ultimate nature and capabilities of matter at all. Really, then, it appears to be nothing

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* Herbert Spencer. *First Principles* (Second Edition), p. 73.

**North British Review*, Feb., 1864.

less than unscientific and illogical to endeavor to explain the inexplicable nature of a known entity by the supposition of another entity ten-fold more inexplicable than that which it endeavors to explain. And the absurdity becomes much greater and more apparent when that which was sought to be explained confessedly remains as inexplicable as ever.

20. *All-Sufficiency of Matter and Motion.*—Matter and Motion can, in all probability, account for every phenomenon of which we are sensible: in fact, the latter appears to be an essential property of the former. How matter originally came to be endowed with this property is something that we do not know at the present time; but we may possibly gain some idea of it in this work, and perhaps find it out fully next year, or next century. That motion appears to be an invariable characteristic of matter in every form and state known to us is sufficiently evident from the undulatory theory of heat and light. The book lying upon the table, the stone resting upon the ground, are each a volume of motions; and by the different motions of each are we alone able to distinguish them as to color, form, heat, sound, taste, smell, or touch. This much is now generally admitted. But we may go still further. Our own bodies are complex aggregates of motions of many different kinds; and we become sensible of the properties of the different kinds of matter simply as the motions of the latter affect the motions of our bodies.

21. *One Grand Chain of Causation.*—It is a noble idea, which originated, it is said, in the great min Newton, that all the different forms of matter fro suns down to molecules are the products of some stage or other of one continuous process of cosmical evolution in the past. This idea now appears to have the

concurrence of all speculative minds. And if this idea (modified in accordance with the new theory only by regarding the process even now as in full blast) is the true one, what we should at once endeavor to do is to trace all the successive stages of this process from the original, homogeneous, rotating spheroid of star-mist down to the microcosmic domains of the atom.

Now if, from the rotation of the original spheroid, the planets have derived, by this process of evolution, the circular motions which we observe them to have, may we not reasonably suppose that the successively smaller and smaller divisions of matter which would result from the more and more advanced stages of the same general process, also have circular motions, just as the planets have? We can thus dimly perceive some further justification, aside from spectral evidence, for the notion that molecules move in circular orbits, just as the planets do. This notion is directly opposed to the kinetic theory, which is the one now taught and which implies only rectilineal vibrations of molecules. It is also of some importance in the new theory; and for these reasons, perhaps, it is entitled to still further consideration.

22. *Orbital Molecular Motion.*—Probably the best justification of the idea of molecular orbital motion is the perfect manner in which the phenomena of heat, light, gravitation, etc., admit of explanation by means of it. Thus heat is admitted to be a species of motion: increasing the heat of a body therefore increases its quantity of motion; and increasing its motion causes the body to expand—in precisely the same manner that a planetary orbit would expand if the planet's absolute motion were increased. The intermolecular connections furnish the means by which

motions are communicated from one molecule to another; for while one set of connections would lie between the revolving parts of the molecules and the central parts, another set would connect the revolving parts of contiguous molecules with each other. These latter would therefore serve much the same purpose for the molecule that the side-bars or connecting-rods do for the driving-wheels of a railroad engine: the power being applied to one wheel, or molecule, the connecting-rod communicates it to the adjoining one—the sole difference being that in the molecule the connecting-rod is highly elastic while in the engine it is rigid.

This also explains the various heat-conducting properties of various bodies, which would obviously depend upon the degree of their structural complexity. If the structural complexity is great, the nearly contiguous molecules would be connected in a very round-about way. In this case we should obviously have a poor conductor. In a good conductor there would be a parallelism of the planes of motion chiefly to one particular axis of the body, and a simplicity of structure admitting the direct connection of the bodies circulating in these planes. In some bodies, such as certain crystals, the molecular motions lie chiefly in one plane, in which therefore the conduction is good, but poor in the transverse direction.

The undulatory theory of heat and light would thus be transformed into a circulatory theory. And, indeed, the circulations are really undulations in the planes of motion, so that the two theories are, in this respect, by no means so different as they might at a first glance appear.

23. *Orbital Planetary Motions and Cosmical Gravitation.*—Now if the molecules have orbital motions like

the planets and are yet connected together by material bonds, why may we not reasonably suppose that the planets—which we know to have orbital motions, and which are subdivisions of matter derived from an intermediate stage of the same general process of evolution which produces the molecules—are also connected together by material bonds like the molecules? On the basis of this supposition we can at once approximately understand how the heat and light motions of the heavenly bodies are transmitted to one another by means of the molecular motions of the material bonds connecting them. And we can also faintly perceive the mechanism by which the planets are held to the central body of our system, and by means of which also a body falls to the Earth's surface. For the connecting-rods of the molecules reasonably possess strength just like other material, although they also possess great elasticity. The vast numbers of them in the bond holding a planet to the Sun would thus be enabled to withstand the ordinary strain of the circulating planet. But if the motion of the planet would become greater than ordinary, the elastic bond would gradually yield, the planet would move out into a larger orbit where the centrifugal strain would become less, and so an equilibrium would be attained and the planet prevented from moving away from the Sun. If the motion of the planet would become less than ordinary, the elasticity of the bond would draw the planet inwards where the centrifugal strain would become greater, and thus check the planet from greater approach towards the Sun.

24. *Orbital Molecular Motions and Terrestrial Gravity.*—Also it is manifest that the innumerable bonds con-

necting a planet—the Earth, for instance—with the other heavenly bodies, would form an atmosphere of connective substance all around it, to the density of which any one of the bonds contributed but a very small degree. Now, at the Earth's surface, the density of this connective atmosphere would be comparatively great, and it would gradually diminish with the distance away from that surface; in fact, the density would vary inversely as the square of the distance from the Earth's center, as very simple geometrical considerations may readily demonstrate. Suppose now a body suspended in this connective atmosphere (the presence of the air being disregarded for the sake of simplicity), the connective substance pervades every molecule of the entire body; the connective molecules form bonds, or connecting-rods, with the molecules of the body, and the latter molecules by means of the circular motions of the former and the elasticity of the connecting-rods uniting them, are strained or drawn in all directions. But, as more connecting-rods are joined to the molecules of the body on the lower than on the upper side, because the lower connective density is the greater, there is a surplus of strain upon the body from below, and consequently it is drawn toward the Earth's surface.

25. *Necessary Incompleteness of these Views.*—Thus by means of this new connective theory of cosmical arrangement, we obtain some conception of the mechanism of the phenomena about us without any resort whatever to the occult notion of force. We have indeed used the term *elasticity;* but there is nothing involved in this term that is not involved in matter and motion. Elasticity, in the connective theory, is nothing more than the centrifugal tendency of the orbital

motions asserting themselves against external pressure or strain.

It is necessary to caution the reader, however, that the ideas of the mechanism of the processes of nature which we have thus hastily obtained, are extremely crude and incomplete. To gain an approximate idea of the mechanism of nature, we must, as already intimated, begin at the beginning, say of the Solar System as such, that is, the primordial slowly rotating solar spheroid, and we must follow its development into planets, satellites, sub-satellites, comets, meteorites, etc., step by step down to the generation of the molecule. With the still crude but proximate ideas thus gained, we are to go over the same ground again, beginning with a more extensive system than that of our Sun. And after thus correcting and re-correcting our ideas many times, at the cost of almost infinite labor and pains, we may hope to attain to nearly perfect views of the processes of cosmical evolution which we see going on around us.

26. *Rectilineal Molecular Motion.*—In the preceding introductory remarks regarding the new theory, molecular motion has been spoken of as circular or orbital. As the assigned limits of this work will not permit the vast domains of molecular phenomena to be even cursorily glanced at, it may be well to remark here that, although all molecules undoubtedly exhibit signs of circular motions, all molecular motions are not necessarily circular. In the gaseous and vaporous states of matter, it is clearly deducible from the new theory that some molecular motions are nearly rectilinear—just as in the Solar System the circular motions of the planets are accompanied by the almost rectilinear motions of comets and meteorites. Indeed it is by the transforma-

tion of orbital molecular motions into rectilinear paths, through the application of heat or some other form of motion, that the generation of gases and vapors from the solid or liquid state, and the accompanying pressure, are explicable by this theory. The same explanation extends also to the case of explosives, in which many kinds of circular motion (though by no means all) of the highly compound molecules are in an instant transformed into one rectilinear motion, the velocity of which is the aggregate velocity of all the different kinds of orbital motions destroyed.

27. *Purpose and Connection of these Observations.*—These phenomena all belong to the microcosmic domains of heat, light, electricity, magnetism, etc., the consideration of which properly follows that of the grosser cosmical phenomena; but which we shall not have the opportunity to discuss in this work. The sole justification for the introduction of the one or two instances from this domain in this place is the endeavor to elevate the new theory to such a degree of our respect as it is hoped will gain for it at least the serious attention of the reader in the more important investigations which are to follow.

We shall now assume, simply as a matter to be credited or discredited from the results of the following inquiry, that the heavenly bodies are all connected with each other by material bonds, or *connexions*, as we shall henceforth distinctively term them. If such connexions really exist, it seems obvious that, as the distance between any two bodies diminishes, the substance of the connexion between them would accumulate upon each; and that, as the distance between them increases, the connective substance would be drawn out of their respective atmospheres. Now it seems reasonable to suppose that, when the connective substance would accumulate to a great extent upon the the Earth in this manner, certain meteorological effects would be produced, and that, when it is drawn away from the Earth to an equal extent, opposite meteorological effects would follow—both of such magnitude as to admit of observation and measurement. Extensive and long-continued accumulation of connective substance would be most likely to cause increased atmospheric electricity and precipitation; and excessive and long-continued withdrawal of the connective substance would likely cause a diminution of these elements.

Actual observation appears to have demonstrated that we have periods during which atmospheric electricity and precipitation are excessive, and others during which they are deficient. And if, after computing the periods during which the interplanetary connective substance would accumulate in, and be withdrawn out of, our atmosphere, it be found that these correspond respectively to the excessive and the deficient periods of atmospheric electricity and precipitation as far back as records extend, we shall thus not only have excellent ground for believing that the assumption with which we started is true, but we shall also have a valuable basis for at least a partial prediction of the weather and other related phenomena. And if also we find that all the hitherto mysterious phenomena within the scope of our inquiry, such as the sunspots, the zodiacal light, the solar corona, are incidentally explained in a clear and simple manner by means of the assumed interplanetary connexions, as the inquiry proceeds, it would seem at least not to imply any presumption to place the connective theory on the same plane of trustworthiness and credibility with the theory of gravitation. The just competition of the two in the subsequent investigations will surely entitle the one or the other to an impartial judgment from the reader as to its superior ability to explain and account for the various cosmical phenomena.

28. *Premises and Scope of this Portion of the Inquiry.*—Let it be granted, then, that every planet of the Solar System is connected with the Sun by a *primary* bond, or connexion, with every other planet by a *secondary* connexion, and with other heavenly bodies by connexions of various degrees of kinship; and let it further be granted that these planetary connexions are in every case material and highly elastic, though they may quite reasonably decrease in density and some other important respects with the remoteness of relationship of the bodies between which they subtend, and though even the densest or primary connexions may be almost as tenuous as entities now regarded as immaterial.

We are to consider the case of the Earth as possibly affected by these supposed planetary connexions. As our planet circulates annually around the Sun, it alternately approaches towards, and recedes from, each of the other planets as well as the Sun itself; and these alternate approaches and recessions involve, according to our supposition, alternate accumulations and drains of the connective substance in our atmosphere. Presuming that these accumulations and drains would affect the quantities of electricity, precipitation, etc., we are to calculate their actual amounts for each month in the year in the case of each of the most important bodies of the Solar System for a period of years sufficient to determine the law, if such there be, which governs the relative quantity of connective substance in our atmosphere at any time.

29. *Classification of Connexions.*—At a first glance the vast number and various kinds of connexions, which, according to our premises, would fall upon the Earth, appears amazing; and the reduction to order and the determination of their variations seem utterly impossible. Moreover,to determine the relative amount of connective variation due to any body with which the Earth is connected, the relative mass of the body is an indispensable datum; yet this datum is ascertainable at the present time only for the bodies primarily, and, for a portion of the bodies secondarily, connected with us.

Fortunately, however, it is not necessary for our present purpose, to determine the relative quantitative variations of the Earth-connexions of every order. In fact, we need only consider such variations in the case of primary and secondary connexions, or just in those cases alone in which it is now possible to do so. Connexions more remote than the secondary, and even a few secondary connexions themselves, are with bodies so distantly related to us that their masses, magnitude, and often, perhaps, their existence are absolutely unknown to us. All these connexions will, therefore, be grouped in one class, which will be designated the *sidereal* class or factor; and as both the period and the linear amount of variation is almost mathematically identical for every member of this class, it is only necessary for us here to consider their quantitative difference upon opposite sides of the Earth, and regard this difference as if it were owing to a single heavenly body. All the connexions which fall upon the Earth's surface may, therefore, be included in the three groups—primary, secondary, and sidereal.

The primary group consists of only two members, or that with the Sun and that with the Moon. The secondary group may be divided into two sub-groups, or those connexions which extend towards the bodies which are immediately derived from the Sun and those which extend towards the bodies from which the Sun itself, in accordance with subsequent deductions from our premises, is immediately derived. But the latter of these is really included in the sidereal factor, and, therefore, does not require a separate consideration for the present purpose. It may subsequently receive our attention, however, in connection with another subject. So that we thus finally arrive at four different factors to which the supposed connective variations in the Earth's atmosphere would be due; *viz.*, the sidereal, the solar, the lunar, and the planetary.

Now, there is one thing that distinguishes the planetary and the lunar factors from the other two, *viz.*, the incommensurableness of their periods with the year. The sidereal and the solar factors each go through a complete cycle of variations in almost precisely one year; whereas each planetary variation goes through a complete cycle only in the synodic periods of their respective planets with the Earth; and the lunar variation has a period of thirteen and three-fourths days—each of which is incommensurable with the Earth's period. The effect of the former two factors would, therefore, be almost exactly alike in each successive year; whereas the effects of the latter two would not be alike in every year, but only in successive periods or cycles of years. The latter are, therefore, independent of the former so far as these periods of years are concerned; and once these periods are determined they remain wholly unaffected by the other factors.

Now, the lunar factor, although of some consequence in small portions of time, such as a day, would have scarcely an appreciable effect on a table of monthly values. Although its period is incommensurable with the year, yet that period is such that, in any particular month, its algebraic effect is comparatively small; so that the main characteristics of the longer periods of connective variations upon the Earth, as ascertained from the planetary connexions alone, will not be measurably affected by this any more than by either of the other two factors. This will subsequently be shown more in detail.

We may, therefore, conveniently begin with the planetary factor of the connective variations in our atmosphere in order to ascertain the longer periods of these variations, and afterwards we may add in the effects of the other factors and thus determine their shorter periods.

30. Factors of the Planetary Connexion Variations.—The relative masses of the seven planets with which we have assumed the Earth to be connected, though not very accurately agreeing with those which the new theory eventually predicates, are yet sufficiently approximate for our present purpose. We observe first that, whatever the magnitude of the planet may be, the connexion joining it with the Earth will manifestly have the same sectional area at the Earth's surface as the Earth itself; and second, that the mass-values for equal linear units of this uniform sectional area obviously depend upon the mass-values of the bodies to which the connexions respectively extend. With these preliminary observations, we are now ready to begin.

Commencing with the planet Mercury, we find that the linear variation of its connexion with the Earth would be 71,500,000 miles, or the diameter of Mercury's orbit; and also that this variation takes place in 58 days, or half its synodic period with the Earth. To obtain the volume-variation corresponding to this linear variation, we multiply the latter by 49,000,000, or the sectional area of the Earth in square miles. Then to obtain the mass-variation, we multiply this last by the mass-value of the planet. This will give us the *relative* mass-variation of this connexion with respect to that of some other planet, obtained in the same way. If we were to obtain the *absolute* mass-variation, we should have to multiply the relative mass-variation of the connexion by the mass-value of the connexion itself, as compared with that of an equal volume of some known standard substance. But we do not at the present time know, in fact we do not appear to have the means of knowing, what this absolute mass-value of a connexion would be. We know that the connective substance, if it exists at all, must be extremely attenuated, so much so, in fact, that it would be quite independent of the attraction of gravity, and, therefore, it would possess, as such, no degree whatever of the peculiar property which we call weight. And we can tell also what the mass-value of one connexion would be with respect to, or in terms of, that of another. But this appears to be the limit of our present knowledge in this respect. As to how many grains of substance there are in a cubic yard, or a cubic mile, of any particular planetary connexion if it were all changed into some form amenable to gravity, we are absolutely in the dark. Therefore, since we must employ only relative mass-values of the planetary connexions, and since Mercury is the smallest of the seven planets, we may as well call the mass of this planet unity; that of any other planet being greater than unity, as its mass is greater than that of Mercury. The mass-variation of Mercury's connexion, then, since the density of that connexion is taken as the standard, will be just the same as its volume-variation.

The linear variation of the Earth's connexion with Venus is 133,500,000 miles, or the diameter of the latter's orbit, and it takes place in 292 days, or half the synodic period of Venus with the Earth. We obtain the volume-variation just as in the case of Mercury; and to obtain the mass-variation we multiply the volume-variation by 12, that being the relative mass-value of Venus, as compared with that of Mercury as unity. The linear variation, and consequently the volume-variation of each of the outer planets is numerically the same; being 186,000,000 miles, or the diameter of the Earth's orbit. The half-synodic period, the linear, volume- and mass-variations, and the mass-value for each of the seven planets are given in the following table; a sixth column being added in which is given for purposes of comparison, the mass-variations of each planet for 1 day.

TABLE I.

PLANETARY CONNEXION VARIATIONS WITH RESPECT TO THE EARTH.*

	Variation-Period, Days.	Linear Variation in Period, Miles.	Volume-Variation in Period, Cubic Miles.	Mass-Values, Mercury = 1.	Mass-Variation in Period, Cubic Miles.	Mass-Variation in one Day, Cubic Miles.
Mercury....	58	71,500,000	$3{,}500 \times 10^{12}$	1	35×10^{14}	6×10^{13}
Venus......	292	133,500,000	$6{,}500 \times 10^{12}$	12	78×10^{15}	27×10^{13}
Mars........	390	186,000,000	$9{,}114 \times 10^{12}$	1½	14×10^{15}	4×10^{13}
Jupiter.....	199	186,000,000	$9{,}114 \times 10^{12}$	4,771	$43{,}483 \times 10^{15}$	$21{,}851 \times 10^{13}$
Saturn.....	189	186,000,000	$9{,}114 \times 10^{12}$	1,428	$13{,}015 \times 10^{15}$	$6{,}886 \times 10^{13}$
Uranus.....	185	186,000,000	$9{,}114 \times 10^{12}$	221	$2{,}014 \times 10^{15}$	$1{,}089 \times 10^{13}$
Neptune....	184	186,000,000	$9{,}114 \times 10^{12}$	258	$2{,}351 \times 10^{15}$	$1{,}278 \times 10^{13}$

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* The masses, periods, and distances of the planets here employed are those given by Prof. Simon Newcomb, in his *Popular Astronomy*, sixth edition.

As for the less important members of the Solar System with which the Earth is secondarily connected, such as the satellites, minor planets, and perhaps some comets, even their aggregate mass, so far as known, would be comparatively small; and, besides, these bodies are always distributed on all sides of the Earth, so that their quantitative excess on one side as compared with the opposite side is all that would really operate to affect connective variation upon the Earth. And this excess, in view of the extremely small individual masses of the bodies, and their comparatively small aggregate mass, is quite safely negligible.

Indeed, a glance at the last column of Table I shows us that the same is true also of the three smaller of the major planets; the variations in equal times due to all but the four outermost of which sink into comparative insignificance. In fact we observe that Neptune, the most distant planet, is nearly fifty times more effective than Venus, the nearest. So that, dividing the value of each body in order that the value of the greatest may be represented by three figures for convenience in tabulating, all the three inner planets together drop below unity, and therefore practically out of the calculation.

31. *Amount of the Planetary Factors.*—Now, it is possible that all of the four outer planets may be nearly in conjunction, or have nearly the same heliocentric longitude; and the drains or accumulations of their respective connexions may, therefore, affect the Earth's atmosphere all at the same time. Summing up the values of the average variations of the connexions of these bodies in the last column of Table I, taking half the sum for the variations caused upon these bodies themselves, and multiplying by ten to allow for the maximum rate of variation owing to the curvilinear path in which the Earth moves, we have, possibly, 16×10^{11} cubic miles of connective substance, either drawn out of, or accumulating in, our atmosphere in

a single day. This tremendous volume is about one hundred million times that of our atmosphere, estimating its height, as is commonly done, at one hundred miles.

But, on the other hand, the outer limits of our atmosphere, and especially of the connective atmosphere, according to the principal supposition here made, must be far more remote than one hundred miles. Moreover, the least density, that of Mercury's connexion is taken as the standard, the density of Jupiter's connexion being some 4,800 times greater. Also the connective substance, or ethereal fluid, which is thus supposed to ebb and flow in our atmosphere, is really imponderable matter—matter not subject to the attraction of gravity because it is matter similar to that whose molecular motions really constitute the attraction of gravity—and thus does not admit of comparison with matter as we are sensible of it. The most perfect vacuum attainable with a Sprengel pump has a density of only $\frac{1}{390\,000\,000}$ of an atmosphere; yet the density of this vacuum must be immensely greater than that of a planetary connexion, for the reason that the former possesses still the undiminished density of the Earth's connective atmosphere to which each of the innumerable terrestrial connexions composing it must contribute but a minute degree.

It is contended here simply that an increased pressure or density of the connective substance in our atmosphere, manifested, perhaps, in the phenomena of earth-currents and auroras, may induce the transformation of a portion of the imponderable fluid into ponderable forms, affecting barometric pressure and atmospheric precipitation; and, also, that an extensive drain upon the connective fluid in our atmosphere may induce transformation of sensible gases and vapors back again into the imponderable state and have opposite meteorological effects. In accordance with this not unreasonable view, our calculations will now be resumed.

32. *Monthly Variations of the Planetary Factor.* —Dividing the mass-values of the connective variations as given in the fifth column of Table I by 10^{17}, so that the figures may be conveniently tabulated, we have 435 for the value of that due to Jupiter, 130 for that due to Saturn, 20 for that due to Uranus, and 24 for that due to Neptune, in the respective half-synodic periods of these planets with the Earth. The values of the connective variation of the other planets in their respective half synodic periods are each less than unity of this scale, and are, therefore, disregarded.

Between opposition and conjunction* of these planets with the Earth, the intervening connective substance would accumulate in our atmosphere, and, between conjunction and opposition, it would be drawn out. The times of these conjunctions and oppositions are, therefore, to be ascertained in the case of each planet, plotted down in equal rectangular spaces representing years, each divided into twelve spaces representing months, and in the monthly spaces are to be placed the figures denoting the values of the connective variations due to the respective planets, based on their direct distance-variations for that month. Figures denoting approach of the Earth and a planet, or accumulation of their connective substance in our atmosphere, are given in full-faced type, and those indicating the contrary conditions are given in Roman type. Following is a table giving these values for the four great planets during the years 1888–91, inclusive:

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*If they could conveniently be avoided, these terms would not be employed, as they must be used here in a sense directly opposite to that usually given them. Throughout these pages two planets are regarded as in conjunction when they are together on one side of the Sun, or have the same heliocentric longitude; and they are regarded as in opposition when they are on opposite sides of the Sun, or are 180 degrees of heliocentric longitude apart. On the contrary, a planet is usually regarded as being in conjunction when it lies in a straight line passing from the observer through the Sun, whether the planet be on this side or the other of that luminary, and it is regarded as in opposition when it lies in the continuation of the same line from the observer outwards from the Sun. In the former sense the Sun is regarded as the center; in the latter the Earth is so regarded, and some of the planets consequently have no opposition at all. This view, however, is unsuitable to the considerations here involved, and, therefore, the employment of the terms in the first sense is necessary; if they are employed at all.

TABLE II.

MONTHLY VARIATIONS OF THE PLANETARY CONNEXIONS UPON THE EARTH, 1888–91.

		Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1888.	Jupiter..	88	99	88	60	..11	38	76	94	94	76	38	..11
	Saturn..	..	15	25	31	29	21	.. 7	8	24	33	33	24
	Uranus..	5	4	.. 1	1	4	5	5	4	1	.. 1	4	5
	Neptune	4	6	6	4	.. 3	2	4	6	6	4	.. 2	2
1889.	Jupiter..	60	88	99	88	60	..12	39	76	94	94	76	38
	Saturn.	8	..7	21	29	31	25	15	..	16	30	34	30
	Uranus..	5	4	1	.. 1	4	5	5	4	1	.. 1	4	5
	Neptune	4	6	6	4	.. 2	2	4	6	6	4	.. 2	2
1890.	Jupiter..	..	50	83	103	97	69	..25	25	69	97	103	83
	Saturn..	16	..	15	25	31	29	21	.. 7	8	24	33	33
	Uranus..	5	4	1	.. 1	4	5	5	4	1	.. 1	4	5
	Neptune	4	6	6	4	.. 2	2	4	6	6	4	.. 2	2
1891.	Jupiter..	50	..	38	76	94	94	76	38	..11	60	88	99
	Saturn..	24	8	..7	21	29	31	25	15	..	16	30	34
	Uranus..	5	4	1	..	2	5	6	5	2	..	2	5
	Neptune	4	6	6	4	.. 2	2	4	6	6	4	.. 2	2

The planet Jupiter was in conjunction with the Earth May 28, 1888; in opposition with it December 11, 1888; again in conjunction June 24, 1889; again in opposition January 12, 1890; again in conjunction July 30, 1890; again in opposition February 22, 1891; and again in conjunction September 5, 1891. Following conjunction up to opposition, the full value (435) of Jupiter's periodic variation is distributed among the intervening months in approximate accordance with the versed-sine approaches towards the planet for each month. The type in which these figures are given indicate recession of the two planets and consequent diminution of their atmospheres. Following opposition up to conjunction, the full value of the periodic variation of Jupiter's connexion is distributed in a similar manner, but in type indicating approach of the bodies, and consequent accumulation of their respective atmospheres.

Saturn was in conjunction with the Earth January 23, 1888; in opposition with it July 25, 1888; in conjunction February 5, 1889; in opposition August 15, 1889; in conjunction February 18, 1890; in opposition August 27, 1890; in conjunction March 4, 1891; and in opposition September 10, 1891. The full value of its periodic variation (150) is distributed among the intervening months, as in the case of Jupiter. And similarly also with Uranus and Neptune.

33. *Deductions from These Variations.*—It will be observed that in any particular month the Earth is approaching some of the planets, while from others it is receding; the figures denoting the former being positive with respect to the Earth's atmosphere, and those denoting the latter negative. The quantitative effect of all four planets upon our atmosphere in any

month will, therefore, be the algebraic sum of their individual values for that month. Following are the figures for the same four years, these sums in the case of each month having been obtained; a thirteenth column being added, in which is placed the algebraic sum of all the monthly sums of each year:

MONTHLY AND YEARLY SUMS OF THE PLANETARY CONNEXION VARIATIONS UPON THE EARTH, 1888–91.

	Jan.	Feb.	Mar.	Apr.	May.	J'ne.	July	Aug	Sept	Oct.	Nov.	Dec.	Year.
1888	**89**	**82**	**58**	**24**	24	62	84	84	65	38	1	**38**	65
1889	**69**	**78**	**73**	**54**	**23**	16	55	74	73	59	36	5	21
1890	**17**	**48**	**63**	**73**	**60**	**37**	**3**	30	56	68	64	47	**36**
1891	25	**6**	**26**	**51**	**61**	**60**	**49**	**24**	**7**	40	54	62	**89**

We observe from these results that in 1888 the Roman figures, extending from April to November, indicate a relative drain upon our atmosphere during that time, and, according to the theory here advanced, a consequent relative deficiency of atmospheric, electricity and precipitation. In 1889 this deficient or dry season extends from May to January 1890, and the next extends from July 1890 to February 1891. The figures for the remaining months of 1888, 1889, 1890, and from January to September 1891, indicate relative accumulation of connective substance in our atmosphere, and a consequent relative increase of electricity and precipitation.

It is further to be observed that the algebraic sums of the monthly figures for 1888 and 1889, as given in the thirteenth column, indicate that the drain upon our atmosphere, on the whole, has been in excess in these years, and that consequently they will be comparatively dry. The annual results for 1890 and 1891, similarly obtained, indicate that the accumulation in our atmosphere has been in excess, and that consequently these years will be comparatively wet. And, finally, it is to be observed that the indicated change in *the year column* from dry to wet occurs about the time of the present sunspot minimum. This coincidence in just the one instance might of course have arisen out of mere chance; but if, in carrying our calculation back say forty or fifty years, it be found not only that this change from dry to wet years is always indicated to take place at, or very nearly at, sunspot minimum, but also that the opposite change of wet to dry years is always indicated at, or nearly at, sunspot maximum—or, in other words, that the longer periods of the planetary connective variations which we are now on the point of determining are almost exactly coincident with the sunspot periods—there surely must be something besides mere chance that determines so exact a parallelism of the two phenomena for so long a period.

34. *Monthly and Yearly Variations of the Planetary Factor for the Period 1840–1903.*—We proceed at once to this test. The times of opposition and conjunction of each of the four outer planets with the Earth have been ascertained and plotted down for the period of years 1840 to 1903 inclusive, in precisely the same manner as has been done for 1888–91.* The negative or the positive value of each planet has been determined for every month of this period, the algebraic sum of these for each month obtained and tabulated, and the algebraic sum of these monthly sums found for each year and placed in the year column. A fourteenth column is added in which is given the maxima and the minima of sunspots, and a fifteenth column in which is shown the maxima and the minima of the connective variations upon the Earth. Following are the results:

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*I am much indebted to Mr. G. W. Hill of the *Nautical Almanac* office, Washington, D. C., for kindly furnishing for this work the dates of the oppositions (i. e. conjunctions here) of Jupiter and of Saturn, each with respect to the Earth, for the period 1726 to 1891 inclusive. For the other years which are given and for the planets Uranus and Neptune, the times of conjunction and opposition have been computed by means of the synodic periods of the planets with respect to the Earth, and by giving rough values to the equation of the center. The maximum error by this method can not exceed three or four days, an error which in the case of the two minor planets, and in a table of *monthly* results is safely negligible.

TABLE III.

MONTHLY AND YEARLY SUMS OF THE PLANETARY CONNEXION-VARIATIONS UPON THE EARTH FOR THE PERIOD 1840–1903.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.	Sunspots.	[illegible]
1840.	122	129	102	56	7	62	97	134	132	90	27	41	80		
1841	98	134	126	109	52	11	69	112	132	127	94	99	81		
1842	60	99	129	185	115	55	12	82	132	140	130	80	12		
1843	90	44	100	186	161	110	57	14	82	125	146	125	76		Max.
1844	76	11	42	106	131	127	95	47	15	88	134	136	109	Min.	
1845	111	65	0	80	105	122	114	90	44	19	68	109	171		
1846	138	114	74	19	45	94	114	115	87	69	20	69	78		
1847	100	109	94	58	5	44	81	95	95	72	82	17	42		
1848.	55	88	98	79	50	15	29	61	76	74	56	81	42	Max.	
1849.	3	84	60	69	68	46	21	8	22	57	65	59	77		
1850.	40	13	90	48	60	60	48	80	5	22	46	57	94		
1851	60	46	88	2	37	48	60	60	51	26	10	85	81		Min.
1852.	55	88	47	45	15	18	41	68	71	64	89	6	88		
1853	81	50	76	71	57	26	11	42	71	84	78	80	14		
1854.	9	81	68	65	62	68	88	5	47	81	92	80	42		
1855	43	0	47	78	94	91	75	58	19	65	98	104	118		
1856	98	87	16	29	72	101	106	91	49	9	57	95	128	Min.	
1857.	119	107	76	58	81	94	120	124	105	56	0	54	120		
1858	96	102	136	96	35	21	86	116	124	89	62	1	84		
1859	88	109	185	122	88	26	66	90	120	175	102	54	0		
1860	6	67	109	151	119	89	34	84	92	129	134	107	52	Max.	
1861	53	81	88	116	126	111	79	16	41	96	126	190	97		Max.
1862	99	49	82	79	116	127	110	87	13	44	97	125	119		
1863	127	90	42	80	82	113	121	101	86	9	69	97	116		
1864.	122	119	84	60	83	84	113	116	86	37	4	50	85		
1865.	96	119	112	78	64	25	77	105	113	94	84	5	88		
1866.	49	90	111	107	75	31	30	75	100	106	90	59	8		
1867	5	42	78	100	99	77	27	15	61	59	94	84	88	Min.	
1868	27	41	22	68	56	28	81	45	8	41	74	94	69		
1869	88	60	34	19	44	74	82	72	52	18	25	88	100		
1870	61	79	61	86	6	80	82	77	79	58	86	8	72		
1871..	42	61	88	74	51	14	95	52	71	75	62	55	7	Max.	

TABLE III—CONTINUED.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.	Sunspots.	Compass Variation.
1872	1	86	60	77	80	52	[illegible]/15	18	45	68	76	65	34		Min.
1873	43	[illegible]/9	36	54	76	79	62	[illegible]/20	1	24	82	76	105		
1874	74	61	[illegible]/30	92	53	79	64	60	86	[illegible]/9	82	66	67		
1875	79	81	66	[illegible]/65	19	53	82	90	77	46	[illegible]/7	80	63		
1876	67	92	95	78	[illegible]/40	21	77	89	97	88	55	[illegible]/18	66		
1877	21	73	99	105	90	[illegible]/44	9	91	95	100	102	69	0		
1878	[illegible]/19	89	92	108	114	98	[illegible]/45	16	70	102	115	105	38	Min.	
1879	71	[illegible]/28	47	84	123	129	106	[illegible]/55	11	89	114	101	128		
1880	115	91	[illegible]/19	82	98	123	130	111	[illegible]/50	5	73	119	127		
1881	129	122	78	[illegible]/51	37	98	130	107	100	[illegible]/62	4	70	128		
1882	114	109	127	90	[illegible]/38	40	101	126	128	106	[illegible]/53	14	63		Max
1883	70	117	121	116	61	[illegible]/20	38	95	124	126	100	[illegible]/55	0	Max.	
1884	14	90	122	121	110	66	[illegible]/5	53	97	117	119	92	35		
1885	[illegible]/43	74	90	117	124	101	[illegible]/65	6	56	98	114	108	101		
1886	72	[illegible]/29	36	70	101	104	69	52	[illegible]/4	47	91	109	101		
1887	100	70	[illegible]/25	27	74	96	96	78	[illegible]/41	1	48	79	65		
1888	62	82	58	[illegible]/24	24	65	94	94	60	[illegible]/55	1	25	65		
1889	69	79	73	54	[illegible]/25	18	55	74	75	59	90	[illegible]/3	31	Min.	
1890	17	45	68	78	80	37	[illegible]/6	30	56	69	64	47	26		
1891	[illegible]/25	6	26	51	61	60	49	[illegible]/24	7	40	54	69	59		Min
1892	28	45	[illegible]/16	18	42	57	82	61	40	[illegible]/11	32	47	105		
1893	66	74	66	67	[illegible]/2	56	62	90	79	61	26	4	98		
1894	45	66	98	20	57	[illegible]/20	25	57	55	91	79	44	29	Prob. Max.	
1895	8	47	80	87	94	83	[illegible]/51	22	62	98	105	95	82		
1896	29	[illegible]/7	47	88	113	106	80	[illegible]/20	27	71	106	115	59		
1897	100	88	[illegible]/8	47	91	116	114	90	45	62	81	120	109		
1898	128	96	[illegible]/52	1	65	107	126	115	51	[illegible]/21	45	94	111		
1899	127	125	96	[illegible]/45	7	89	107	129	121	86	[illegible]/26	52	99		
1900	108	132	128	96	[illegible]/29	33	78	118	127	118	79	[illegible]/16	55	Prob. Min.	Max.
1901	48	100	126	132	89	[illegible]/64	91	81	114	126	111	78	13		
1902	[illegible]/3	50	102	121	117	90	[illegible]/34	35	87	120	128	103	58		
1903	[illegible]/50	2	90	105	122	116	91	[illegible]/51	85	91	120	121	93		

35. *Connection of the Periods of Variation of the Planetary Factor with the Sunspot Periods.*—A glance along the thirteenth and fourteenth columns of this table shows us at once the almost exact accordance for the entire period of the indicated changes of the wet and dry years with the sunspot changes. *All the years in the entire period which are included in a forward direction from the maxima to the minima of sunspots are indicated to be dry, with the exception of five; and all the years included in the same direction from the minima to the maxima of sunspots are indicated to be wet, without a single exception.*

Now these are the longer periods of the connective variations upon the Earth which we have been in search of, and which, as already stated, stand independent of, and unaffected by, any of the other factors except the lunar; and the evidence which they furnish in support of the truth of the essential supposition of the new theory is surprisingly strong and clear. The most fastidious critic would hardly contend that, for a period of some fifty years, the changes from excess to deficiency in our atmosphere of a supposed connective substance, extending in bonds or cords between our world and the other planets, would occur at sunspot maximum, and the changes from deficiency to excess at sunspot minimum—all out of mere chance; for the probabilities appear to be vastly against such chance coincidences in this case. There surely must be a real connection between the changes of the supposed planetary connexions and the sunspot changes with which they are thus seen to coincide. And the more we shall examine into the subject, the more valuable and incontrovertible the evidence we shall find supporting this conviction.

36. *Coincidence of the Variations of the Planetary Factor with the Periods of Atmospheric Precipitation.*—In the first place it may be well to show from the evidence of other inquirers in this department of nature that there *is* an actual deficiency of atmospheric electricity and precipitation in the indicated dry years, and an actual excess of these elements in the indicated wet years, when a certain amount of lag of the actual after the indicated weather is taken into consideration. It is only some fifteen years since these inquiries were first started, and yet the evidence they afford appear to be no less voluminous than it is valuable and conclusive.

Prof. Balfour Stewart, reviewing the results hitherto arrived at, deals extensively with a supposed connection between the height of rivers and the number of sunspots. He finds that the Nile agrees with European rivers and exhibits a maximum at about the time of maximum sunspots.[*] Now the tabular wet years are indicated as following minimum sunspots; and if (for reasons presently to be considered) we consider the lag of the actual precipitation after the time indicated as between two and three years, on the average, the wet periods predicated by the tabular figures would almost precisely correspond to the periods in which the spots were in excess, and the actual dry periods to those in which the spots were deficient.

Dr. Meldrum, from a comparison of Wolfe's sunspot numbers with the rainfall at Madras, 1816–'77, Edinburgh, 1824–'72, and Paris 1824–'72, concludes that there is an intimate connection between sunspots and rainfall. He shows that in a great many places there is a greater rainfall during years of maximum than during years of minimum sunspots, and that this phenomenon repeats itself from one cycle to another.

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[*] *Nature*, XXIII, 237; XXV, 209; XXVI, 448-9.

In a recent issue of *Nature*, (July 7, 1887), Mr. Henry Blanford, in the course of a general investigation of the rainfall of India,* reconsiders the subject in the light of recent data. He especially considers the Carnatic province, consisting of the plain below, the Eastern Ghauts, occupying the southeast of the peninsula, and extending from Cape Comorin to the mouth of the Kistna. Its area is about 72,000 square miles, with the town of Madras situated nearly midway along the coast. The data are furnished by the registers of this and thirty-nine other stations pretty evenly distributed; most of the records extending back to 1864. This province is partially relieved from the local vicissitudes of rainfall characterizing the summer months of Central and Northern India; so that the annual fluctuations of the Carnatic rainfall often differs widely from that of other provinces in the peninsula. The results arrived at by Mr. Blanford are as follows: "The rainfall reached a minimum in 1867" (year of sunspot minimum), "then rose steadily to a maximum in 1872" (one year after sunspot maximum), "and after a drop in 1873, and partial recovery in the following year, fell rapidly to a second minimum in 1876" (two years before sunspot minimum). "From 1877 to 1881, it oscillated considerably, but thereafter rose again, steadily, to a second maximum in 1884" (one year after sunspot maximum), "dropping again in 1885 to something below the average." And this, he justly concludes, "affords, at least, a very high probability that the apparent undecennial fluctuation is no chance phenomenon."

**Indian Meteorological Memoirs*, Vol. III, Part I.

Prof. Cleveland Abbe, says: "If in general the rainfall is above the mean in the years of sunspot maxima, and below the mean in years of minima, then we must have the following equation:

$$\frac{S-s}{s'-S}=\frac{R-r}{r'-R},$$

where large S is the mean value of the sunspot frequency for the whole period under investigation; small s is the mean value for the period during which the sunspot frequency is below the mean; small s′ is the value for the period during which the sunspot frequency is above the mean; R, r, r′, the corresponding rainfall for these years for which S, s, s′ hold good. That the frequency of sunspots has a simple ratio to the rainfall is now evident from the fact that the above equation holds good approximately for fifty-four stations in Great Britain, and thirty-four in America for the interval 1824 to 1867. During this interval the the rainfall was in excess when the spots were in excess, and deficient when the spots were deficient. The excess was .90 of an inch in England and 1.13 inches in America; and the deficiencies were .75 inches in England and .94 in America."*

Prof. Abbe simply shows us, then, that the wet periods which the movements of the planets and their connexions predicate, according to the new theory, are actually wetter than the average, and that the dry periods, similarly predicated, are actually drier than the average—in England and America from 1824 to 1867.

37. *Relation of the Periods of Variation of the Planetary Factors to the Periods of Atmospheric Pressure.*—With respect to the lagging of the actual weather

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Account of Progress in Meteorology in 1879-81, p. 52.

after the planetary and solar phenomena which indicate it, Mr. Frederick Chambers, summarizing the sun-spot studies of Charles Chambers, Brown, Hill, Archibald, Blanford, and Meldrum, and extending their investigations in still greater detail, finds that the epochs of maximum and minimum barometric pressure lagged behind the corresponding epochs of minimum and maximum solar-spotted area at an interval varying from about six months to two and a half years. His conclusions in this respect are briefly (1) that variations of the solar-spotted area are succeeded many months afterwards by corresponding abnormal barometric variations and (2) that abnormal barometric variations in the tropics travel at a very slow rate from west to east, arriving at westerly stations several months before they reach more easterly ones.*

From this and from the researches of Prof. B. Stewart and others, it appears that the lag of the weather after its indications is by no means constant, but varies at different times and places. The foregoing results arrived at by Mr. F. Chambers show that when allowance is made for the lag, the maximum barometric pressure corresponds to the minimum of sun spots, or the lowest ebb of connective substance in our atmosphere, and the minimum barometric pressure to the maximum accumulation of connective substance in our atmosphere.

The probable explanation of this (as we shall subsequently find excellent grounds for believing) is that the excess of connective substance enables the rarer vapors and gases of the air to ascend to a greater elevation, where the attraction of gravitation is less; and that, when the excess is withdrawn and the connective atmosphere sinks below its normal density, the vapors and gases descend where gravitation is more powerful and so cause a maximum barometric pressure.

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* *Nature*, XXIII, 84–110; Cleveland Abbe, *Account of Progress in Meteorology* in 1882, p. 80.

Here, then, we have a complete parallelism of the indicated wet and dry years, not only with the sunspot changes, but with the actually observed periods of excessive and deficient precipitation and the periods of maximum and minimum barometric pressure. This alone would seem to put beyond a doubt the existence of material interplanetary connexions, on the basis of which alone these indicated wet and dry periods have been determined.

38. *Coincidence of the Periods of Variations of the Planetary Factor with the Periods of Atmospheric Electricity.*—But the parallelism may be pushed still further. We know that there is an almost complete correspondence between the number of auroras and the relative extent of black spots on the Sun, as far back as reliable observations extend, the curve of the one being almost exactly parallel with that of the other for more than a hundred years.[*] And as to the nature of the aurora, Mr. W. S. Jevons, after describing the five auroras of August, 1882, says: "I venture to make the suggestion that these coruscations arise from highly tenuous matter (in what Mr. Crookes calls the *radiant state*), projected through the higher part of the atmosphere. My belief is that, during the auroras described, *puffs*, as it were, of radiant matter were discharged at great elevations above the earth's surface."[†]

H. Fritz, in a very complete summary of our present knowledge regarding the aurora,[‡] quotes from Cramer that the auroras change themselves into clouds, the whole heavens being covered with the latter if the former last for a sufficiently long time. Also that Stevenson at Dunse, Scotland, found the annual frequency of cirrus clouds to run parallel with the frequency of the auroras; that Winnecke, from observations at Pulkova, concludes that the cirrus must be considered as the agent of the aurora phenomena; that Weber and Klein and others give data to show that the times of greatest frequency of auroras and sunspots are also the times of greatest frequency of polar bands; that similar parallelisms connect the sunspots with the height of rivers, the rainfall, and numerous other phenomena; that, in fact, the parallelism between every form of atmospheric phenomena and the solar spots, shows the connection to be a real one, although the *rationale* of the connection is not yet made clear.*

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[*] See Prof. Balfour Stewart in *Nature*, XXXIII, 252

[†] *Nature*, XXIII, 149.

[‡] *Das Polarlicht*, Leipzig, 1881.

We know further that the constitution of the atmosphere is variable, higher percentages of some ingredients being present at certain times than at others, and Regnault suspected rightly, when he declared it deceptive to regard the air as of a constant constitution and a fit standard for the specific gravity of gases.†

39. *The Wet and the Dry Seasons of the Year.*—We pass now to another feature of Table III, the wet and the dry seasons of the year. In 1848, *e. g.*, the first half of the year is indicated to be dry and the latter half wet. In subsequent years the dry season pushes more and more towards the latter half of the year, and the wet into the first. In 1858 the first half of the year is again dry and the last half wet. In 1866 these seasons

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* Prof. Cleveland Abbe, *Account of Progress in Meteorology, in 1879-81*, pp. 80-1.

† See Jolly's investigations, *Zeitschrift Oesterreichischen für Meteorologie*, XIV, 228.

again change places. And so on; a complete revolution of a wet or a dry season from a certain portion of the year back again to the same portion, taking, on the average, nearly twelve years. We notice, also, that the interval during which a certain half of the year changes from wet to dry, corresponds to a dry period of years, and that the interval from dry to wet is contemporary with a wet period of years. The wet and the dry periods of years are, therefore, dependent on, and derived from, the wet and the dry seasons. If now we seek for observations corroborating these indicated wet and dry seasons, as we have done in the case of the indicated wet and dry periods of years, we shall almost entirely fail in our quest—for the following various reasons.

First, as already intimated, the precipitation indicated for a certain time may lag behind that time for several months, the period being various at various times and places. Second, our observations cover but a very small portion of the Earth's surface (a mere fraction of even these being easily accessible to one person), and this portion is mainly removed from the tropics, within which the indicated variations would theoretically occur more regularly. Third, both regular and irregular causes, such as wind and ocean currents, and position with respect to mountain ranges and elevation, would, to a very great extent, smooth down the differences of such short periods in most places where observations are made. And, fourth, the effects of the other factors of the connective variations upon the Earth. Indeed, the most powerful factors in producing connective variations upon our planet yet remain to be considered. But as already stated, the the effects of these, with the single exception of the lunar factor, go through a complete cycle in almost exactly one year; so that, while they alone completely mask the indicated planetary factor, they produce no measurable effect whatever upon the planetary periods. The nature and effects of these factors will now very shortly be considered.

40. *Lagging of the Actual Weather.*—With respect to the first of the foregoing reasons, it may be said that the cause of the lagging of the actual weather behind the indicated weather would very probably be that the withdrawal or accumulation of a certain amount of connective substance would be required to effect a change of the normal atmospheric conditions. These normal conditions are indicated in the table for any month or year by a cipher, or zero. Then, if we suppose that, in this normal state of the atmosphere, it required a withdrawal or accumulation of a quantity of connective substance denoted by about 200 on the scale of the figures of the table (which, to convert into actual volumes of the standard density, needs only to be multiplied by 10^{17}) to effect a corresponding measurable change in the actual weather, we observe that this quantitative accumulation or withdrawal would require, in the case of the seasons, from three to four months, and in the case of the periods, from three to four years—more being required in such years as 1871, than in such years as 1884.

The probable reason why such a quantitative variation of the connective substance would be necessary to produce an appreciable effect on the actual precipitation is that, during the first part of the season or period of accumulation, the capacity of the atmosphere to hold vapors in suspension would increase up to a certain limit, owing to the increased volume and quantity of connective substance it contains; and that, during the first part of the period of drain, the capacity of the atmosphere would diminish in this respect down to a certain limit, owing to the diminution of its connective substance. So that, from the normal amount of connective substance in the atmosphere up to the one and down to the other, the normal precipitation would be likely to prevail.

41. *The Solar Factor of the Connective Variation.*—We may now consider the other factors of the connective variations upon the Earth, which yet remain to be computed. As already stated in Art. 29, it was necessary for the determination of the longer periods of connective variations that the planetary factor should alone be computed; the consideration of the other factors being left for a subsequent occasion. This occasion is now at hand; and the variations of the remaining connexions upon the Earth are to be determined as nearly as practicable.

Taking first the Earth's primary connexion with the Sun, we have, from the eccentricity of the Earth's orbit, a linear variation of about 3,000,000 miles in a period of six months. We then multiply this by the sectional area of the connexion at the Earth's surface, in order to obtain the volume-variation, and by the relative density of the connexion to obtain the mass-variation in this period. But what is the relative density of a primary with respect to that of a secondary connexion? At the present stage of our inquiry this question cannot receive a definite answer. The best we can do is to assign a most probable limit, less than which the density of the solar connexion upon the Earth, with respect to that of its secondary connexions, can not be.

According to the connective theory, as well as to the nebular hypothesis, the outermost planets were the first-born of the solar family. Each of the planets as they successively came into existence, appropriated from the Sun a primary connexion, the sectional massiveness of which we may reasonably suppose, depended upon the masses of the respective planets; and it also appropriated a certain portion of the primary connexion of each of the previously existing planets for a secondary connexion between the two. What this portion is, is the point to be determined; and the limit which it can not reasonably exceed may be represented by the fraction having the mass of the appropriating planet for the numerator, and that of the Sun for the denominator. Several reasons might be assigned for a smaller value of this portion of the previously existing solar connexions which the new-born planet appropriates—such as that the restraining functions of the solar connexions would require, and, *therefore*, retain a proportionately greater share of their substance than the functions of the portions forming the secondary connexions between the planets would require, the latter being of a far lighter nature; but there appears to be no reason whatever for assigning a greater value to it.

Thus, when the Earth first separated from the bosom of the parent Sun, it would have a solar connexion, the sectional density of which would be to that of Jupiter's solar connexion, *e. g.*, as the Earth's mass is to that of Jupiter; and it would also appropriate a portion of the solar connexion of Jupiter, at most, not geater than $\frac{1}{326800}$ of its entire substance, the mass of the Earth having a ratio to that of the Sun of 1 to 326,800. Now, if we call the Earth's mass unity, Jupiter's mass will be about 312, and the sectional massiveness of these solar connexions, at equal distances from the Sun, will also be in the same ratio, respectively. At the Sun's surface the sectional density of the Earth's solar connexion is, therefore, 1, and of Jupiter's solar connexion 312. Then the sectional density of the portion of the latter connexion which the new-born Earth would appropriate for a secondary connexion between the two planets would be $\frac{1}{326800}$ of 312, or $\frac{1}{1045}$ of the density of the Earth's solar connexion. We thus arrive at the conclusion that, for equal linear units, the density or mass of the connexion between the Earth and the Sun is at least a thousand times greater at the Earth's surface than that of the connexion between the Earth and Jupiter.

Thus the mass-variation caused in our atmosphere by the solar connexion in a period of six months would be $3,000,000 \times 49,000,000 \times 1,048 = 154 \times 10^{15}$ cubic miles; while the mass-variation caused by the Earth's connexion with Jupiter is $186,000,000 \times 49,000,000 \times 1 = 9 \times 10^{15}$ cubic miles in a period of 199 days. So that, in equal units of time, the influence of the Sun upon the connective variation in our atmosphere is about eighteen times more powerful than the influence of Jupiter. Had this value of the solar connective variation been placed in Table III, the total value of all the planetary connective variations would sink almost into comparative insignificance. But as the period of this solar variation is almost precisely half of a calendar year, every year would be precisely the same as far as this disturbing factor is concerned; and the peculiarities of the table, with the exception of the wet and dry seasons of the year, would remain wholly unaffected. Having thus approximately determined the value of the solar connective variation, we turn now to the connective variation due to the Moon.

42. *The Lunar Factor of the Connective Variation.*—Here we again meet with a difficulty similar to that met with in determining the relative density of the Earth's primary connexion. What is the relative density at the Earth's surface of the Moon's primary connexion with respect to the Earth's primary connexion? Before this question could be answered as elaborately as it ought to be, it would be necessary to discuss the actual operations of the planetary connexions as manifested in the observed attraction of gravitation on the various heavenly bodies. Such a discussion, however, belongs to a more advanced stage of the present work. We must rest content here with the supposition that the actual work which a connexion performs, affords a trustworthy indication of its actual strength or material density. Thus the Earth's primary connexion is capable of withstanding a certain centrifugal strain, and it is known that the Moon's primary connexion is capable of withstanding a centrifugal strain of less than one-half as much. Therefore it seems not unreasonable that the strength, or the material density, of the latter is less than half that of the former; or, on the basis already employed (the relative density of the Earth's primary connexion being 1048 with respect to Jupiter's connexion with the Earth as unity), the relative density of the Moon's primary connexion would be 493. Now the average linear variation of the Moon's primary connexion is about 26,000 miles; and the Moon's mass is $\frac{1}{80}$ that of the Earth. So that, to obtain the mass-variation of the lunar connexion from these data, we have $26,000 \times 49,000,000 \times \frac{493}{80} = 785 \times 10^{10}$ cubic miles. The period of this variation is the

average time required by the Moon to pass from the perigee of its orbit to the apogee; or a trifle over 13¾ days. So that the average lunar variations in one day is 57×10^{10} cubic miles (that is $57\times10^{10}\times4771=272\times10^{13}$ cubic miles, on the scale of Table III); which is $\frac{1}{1500}$ of that due to the Earth's primary connexion, or $\frac{1}{50}$ of that due to the Earth's connexion with Jupiter, or ten times that due to the Earth's connexion with Venus, in the same time.

The lunar variation-period is so short, however, that only $\frac{2}{5}$ of a unit on the scale of the figures of Table III would be required to express the entire mass-variation due to the Moon's connexion in the whole of it. And as there are about 2⅛ of these periods in a month, it will be observed that, for any particular month, the variation of one lunar period will counteract or cancel that of the other; so that the monthly algebraic sum of the lunar variation is, on the average, only $\frac{1}{5}$ of its periodic variation, or $\frac{2}{25}$ of unity of the scale of Table III. There would thus be longer periods of the lunar variation, each of about five successive months, and in each of which the monthly algebraic sums of the variations would be of the same character; *i. e.*, positive or negative. But in these longer periods the actual amounts of the monthly series are just the same as the variations in the shorter periods. And these are of such small value that were they placed in Table II, scarcely a figure of Table III would be affected by their insertion.

43. *The Sidereal Factor of the Connective Variation.*—It might be supposed, at a first glance, that, as the Earth swings towards one side of the Sun, the accumulation of the connexions with the heavenly bodies beyond the Solar System would be about balanced by

the withdrawal of the connexions as it swings toward the opposite side. But this, in all probability, is not the case, for the reason that our world is not situated in the center of the Sidereal System, but considerably to one side of it. One reason we have for believing this is that, in examining the sky with our telescopes in one direction, we see comparatively few stars, and each individual star is clearly and distinctly projected upon the general blackness of the heavens; while, in looking in the opposite direction, the number of the stars is vastly increased and their magnitude so reduced that they appear to terminate in a completely irresolvable nebulosity. So that, in the words of Sir John Herschel,* "Whatever other conclusions we may draw, this (last) must anyhow be regarded as the direction of the greatest linear extension of the ground plane of the galaxy." In the same paragraph, Herschel places this greatest linear extension of the starry sphere in the constellation Scorpius, which is situated nearly in the intersection of the planes of the ecliptic and the Milky Way, and through which the Earth passes in the first half of June. According to our theory, then, the Earth, during the six months of the year preceding, would be approaching the greater portion of the sidereal sphere and leaving behind the lesser portion of it; so that the accumulation of connective substance, owing to this cause, upon the front of the Earth during that time would be in excess of the drain in its rear. Also, during the following six months, the drain would be in excess of the accumulation. Again allowing a lag of about three months, this would cause a comparative excess of precipitation from about the middle of March to the middle of September, and a deficiency from the middle of September to the middle of March.

*Outlines of Astronomy, sec. 798.

It will thus be observed that the *wet* season of the year, owing to this cause, almost exactly coincides with the *dry* season, owing to the solar factor. For the Earth is at perihelion, or at the least distance from the Sun, about the first of January; and, allowing three months of lag, as before, the solar dry season would be from March to October, while the sidereal wet season, as just found, extends from the middle of March to the middle of September. Thus the one factor counteracts the effect of the other, so that, if the two factors were of equal value, scarcely any effect whatever would be assignable to either at the present time. But the actual weather appears to be in very close conformity to the theoretical effects of the sidereal factor. For, from an examination of rainfall statistics over the Earth's surface, it is found that, in the winter season of the Northern Hemisphere, the amount of precipitation is decidedly less than in the summer season.

44. *Connection of the Sidereal Factor and the Wet and Dry Seasons.*—We may stop for a moment to show this more in detail. The Signal Service records of the United States show undeniably that this is the case in that country.* As far back as these records extend, or from 1870 down to 1889, with respect to ten principal Atlantic coast cities, viz., Eastport, Me., Boston, Mass., New York, N. Y., Wilmington, N. C., Charleston, S. C., Savannah, Ga., Jacksonville and Key West, Fla., New Orleans, La., and Galveston, Tex., they show that the average monthly precipitation in all is 4.35 inches; that November, December, January, February, March, April and May are below the mean, the middle month of the period, February, having a max-

*See also *American Weather*, pp. 139—144.

imum deficiency of just one inch; and that June, July, August, September and October are above the mean, the middle month, August, having a maximum excess of about an inch and a half.

Also in *Prof. Papers* No. X, of the United States Signal Service may be found the average precipitation for each month of the year at seventy-two stations scattered over the whole country, as deduced from all the records at the respective stations. Summing up all of these, the average monthly mean is found to be 3.60 inches for the whole area. The precipitation is in excess of this mean in March, April, June, July and August, and below it in September, October, November, December, January, February, and May. In fact, it appears that, the greater the area taken into consideration, the more exactly will the actual results of observation harmonize with the theoretic results of the sidereal factor. It is very noticeable also, that the nearer we approach to the tropics, the more exact is the correspondence. Thus, at the oceanic station, Key West, Fla., in latitude 28° N., the Signal Service records give six months of excessive precipitation, or May to October inclusive, and six months of deficient precipitation, or November to April inclusive.

45. *Coincidence of the Actually Wet and Dry Periods of Years With the Indicated Wet and Dry Planetary Periods.*—The correspondence of the actual precipitation at this station with the theoretic deductions holds not only for these sidereal seasons of the year but, what is more remarkable, it holds equally well for the wet and the dry planetary periods of years indicated in the 13th column of Table III. Thus, for the period of years 1871 to 1889 inclusive, the mean annual precipitation at this station is 39.88 inches, and the

actual variation from this mean for each year is as follows, the theoretical results from Table III for the same years being placed in the third and sixth columns for comparison:

ANNUAL PRECIPITATION AT KEY WEST, FLORIDA,

1871–1889, INCLUSIVE.

YEAR.	Actual Excess or Deficiency.	Theoretic Excess or Deficiency.	YEAR.	Actual Excess or Deficiency.	Theoretic Excess or Deficiency.
1871	5.20 inches	7	1881	**13.22** inches	**138**
1872	8.11 "	54	1882	**1.98** "	**63**
1873	7.13 "	105	1883	**8.36** "	0
1874	7.13 "	87	1884	6.83 "	56
1875	**3.53** "	**88**	1885	5.85 "	101
1876	**1.93** "	**66**	1886	9.75 "	101
1877	**1.73** "	**0**	1887	**3.74** "	85
1878	**9.15** "	**5**	1888	4.30 "	65
1879	**18.66** "	**128**	1889	**12.79** "	21
1880	6.47 "	**127**			

Here the correspondence is complete, except in three of the nineteen given years. In the year 1880 an actual deficiency occurs instead of the excess theoretically indicated, and in 1887 and 1889, instead of the deficiencies theoretically indicated, there are actual excesses. Also the lag of the actual weather after the theoretic indications is only about a year instead of the two or three years which the theory predicates. As we go northwards to New York and Boston, however, this remarkable correspondence becomes less and less distinguishable, although it is still distinctly traceable over the entire country.

Similar correspondences could be given for similar stations in the East Indies, Asia, South Africa and Australia. The seasons of heavy precipitation at Key

West are coincident with the seasons of cyclones and typhoons of the entire equatorial belt, at which seasons all portions of the Earth's surface accessible to the influence of these storms have a maximum amount of precipitation.

46. Relative Amounts and Effects of the Several Factors.—Of course it is not within our power at the present time to compute the actual amount of variation of the sidereal connexions, as has been done with the planetary and the solar connexions. We can not, therefore, determine the relative efficiency of the former with respect to the latter. But if our reasoning is correct in other respects, it must obviously follow that the sidereal variation, from the overpowering effects corresponding to it, must certainly be greater in equal times than the solar and planetary variations.

Since we can not compute the relative efficiency of the solar and the sidereal factors in the seasonal weather changes, neither can we ascertain the relative efficiency of the effective difference between the two and the planetary factor, the value of which is given in Table III. It may be that the planetary factor is nearly as powerful as the excess of the sidereal factor over and above the solar factor, or it may be that the latter is the more powerful. Subsequent investigations may probably determine this point. In the meantime we may in any case reasonably suppose that when a planetary wet or dry season coincides with a similar sidereal season, as in the periods of 1879 to 1883 and 1891 to 1894, more than the ordinary intensity of precipitation and drouth will characterize our summers and winters respectively of these years; and that when the dry season of the one nearly coincides with the wet season of the other, as from 1884 to 1890, and from

1895 to 1900, less than the ordinary intensity of precipitation and drouth which characterize our summer and our winter seasons respectively, may be looked for. Much less than the usual lag would take place in these cases for the reason that, in the first case, the effective cause is greatly strengthened, and, in the second case, normal conditions would always accompany an approximately even balance of the factors.

47. *Incompleteness of Our Meteorological Data.*—But a great deal undoubtedly yet remains to be known regarding the effect upon precipitation of the drains and accumulations of connective substance in our atmosphere. The views here offered are simply those which, from a consideration of the facts so far as they are known, have appeared the most reasonable. Other facts, however, may yet come to light which may considerably modify these views. Moreover, our present system of meteorological observations is very incomplete. In the comparatively few observations made, most nations appear to act quite independently of each other; and of course no observation whatever is made with any reference to the theory here advanced. So that there is not only no digest of the observations of the world as a whole, but there appears to be, in most cases, no digest even of the observations of a single country as a whole. Maps and charts are usually given showing the actual precipitation over the different portions of a country, and the variations of this from the mean monthly or annual precipitation *for each particular locality* (also this mean or standard amount of precipitation itself appears to vary from year to year, whereas an invariable standard should be adopted at least for a period of ten or twenty years). But if the mean monthly or annual precipitation, and the actual monthly and

annual variations therefrom, for the country as a whole, is desired, the inquirer himself must generally perform the almost herculean labor of reducing these data from the raw statistics of each individual locality. Nor can even these be always obtained at one head office; some of the statistics are usually out of print, and various different places must be searched for the manuscript records.

It is urgently needed, for probably the highest earthly welfare of the human race, that a more extensive and complete system of meteorological observations should at once be adopted by all nations, and the general results from each country sent to one central office for more complete generalization. Indeed, comparatively little in the important department of weather prediction can be accomplished until the maze of intricate agents and complex disturbing factors are brought into some organization through some such general system.

48. *Application and Value of these Weather Indications.*—Finally, it must always be borne in mind that the weather predicted by means of the variations of the terrestrial connexions of all kinds apply, not to any particular locality or country, *but to the Earth's surface as a whole.* It may not infrequently happen through local disturbing causes (which, however, may some time not improbably be predetermined), that in certain localities extreme drouth prevails, while over the Earth's surface, as a whole, the precipitation is excessive; or there is excessive precipitation in certain localities while extreme drouth generally prevails. But the instances of this discordance would obviously be comparatively rare; and the indications would necessarily hold good in the great majority of cases, even if the effects of local disturbing causes could not be foretold.

With respect to the wet and the dry period of years, the lag is more regular than in the wet and the dry seasons, and the effects of the disturbing factors are largely eliminated by inclusion of them in nearly equal amounts and kinds in each period. It may generally be confidently relied on that from the second year of a tabular dry period to the second year of a tabular wet period (such as are given in Table III), the precipitation will be comparatively deficient in nearly every locality; and that from the second year of a tabular wet period to the second year of a tabular dry period, the precipitation will be comparatively excessive. If the foregoing calculations prove anything, they certainly prove this. And this alone, from the facility with which these periods may be computed for any future time, is of no small value to the agriculturist, and, through him, to the entire human race.

49. *A Scientific Basis for the Flood Legend.*—It has been observed that a solar wet or dry season is almost exactly one-half of a sidereal year. The difference between the two—less than one and one-half minutes—is very small indeed. But small as it is, it may prove to be of considerable theoretical importance. The length of a solar wet and dry season together is the period of time during which the Earth passes from the aphelion of its orbit around to the same point of its orbit again; and this period does not exactly correspond in length either to the sidereal or the tropical year. A sidereal year is the period of time during which the Earth passes from a straight line joining a so-called fixed star and the Sun around to the same line again; and this period exactly includes a sidereal wet and dry season together and no more. If the line which joins the perihelion and the aphelion of the Earth's orbit

were as fixed, or rather moved as slowly, as that joining the Sun and the star, the sidereal and the solar seasons would be exactly similar in length. But this line, the line of apsides, is not fixed. It has an extremely slow direct motion of nearly 12″ per annum from the star-line; so that the Earth's perihelion makes a complete revolution, from a certain fixed star around to the same star again, in about 109,830 years. Now the longitude of the Earth's perihelion at the present time is 100° 27′, and that of the point of greatest linear extension of the sidereal sphere is about 262°. The line of apsides has, therefore, traversed over 198° since the time when perihelion and the point of greatest extension of the heavens were coincident; which movement has taken place in a period of nearly 60,000 years. At that time, then, the sidereal and the solar seasons exactly coincided, wet with wet and dry with dry; so that instead of the one antagonizing the effect of the other, as at present, both factors would unite in producing a wet season of tremendous precipitation and a dry season in which the Earth's surface would be extremely parched. Sixty thousand years these conditions would supervene with a maximum degree of intensity; and they would continue with slowly diminishing intensity for some 25,000 years longer. After this more than the half of the one factor would be counteracted by the other, and this degree of counteraction would gradually increase down to 4,500 years ago, when it would have been at a maximum, or the two factors would be completely antagonistic. At this time, therefore, the seasonal intensity would have been at a minimum. It is now increasing and, in some 50,000 years, will be again at a maximum.

These are the theoretical deductions, but perhaps they are not wholly entitled to our implicit reliance. The revolution of the line of apsides may possibly be irregular, and such irregularities might very considerably modify the times of the theoretic maximum and minimum seasonal intensity. It is true that we are not aware of any such irregularities; but the periods are so vast compared with the period of our recorded observations, that it would be quite premature to assume that, in the maze-like intricacies of nature, such irregularities did not exist. Still the coincidence of the solar and the sidereal seasons would certainly have taken place at some time in the past, and if our theory be true, they would as certainly be accompanied by extreme drouth and deluges.

The question now occurs to the mind—May not these seasonal deluges be the origin of the legends of the Flood? If man was contemporary with the great Ice Age, as apparently reliable geological testimony goes to prove, he would have ample opportunity to witness and experience the tremendous floods ascribable to this cause; as the most conservative estimate of the period since glaciation is more than 30,000 years, while by far the greater number and the most eminent of geologists place it at six times this duration. It is undeniable that the theory thus furnishes a possible and even plausible scientific explanation of the diluvial legends, and, in any event a contrast of this explanation with that of collision of the Earth with a comet's tail—that of Kant and William Whiston and almost the only other—appears to be by no means unfavorable to the former.

The same explanation would also apply to the periods of excessive erosion of the Earth's surface, which the testimony of the rocks so clearly indicates, and which geologists find so inexplicable, especially in the later geological ages. No more probable explanation of this excessive erosion, followed again by quiescent periods of deposition can scarcely be imagined than the alternate extreme drenchings and parchings of the Earth-crust continued for many thousands of years and followed again by equally long periods of comparative elemental equilibrium and quiescence, as implied by the foregoing deductions from the connective theory.

50. *Connection of the Orbital Period of Jupiter with the Indicated Wet and Dry Periods of Years and with the Sunspot Periods.*—A tabular dry season and wet season together usually aggregate about thirteen months, and generally a year is indicated to be wet or dry according as all of the wet or all of the dry season is included in it. Pushing this inquiry further in the same direction, we observe that the synodic period of the great planet Jupiter is also thirteen months, and that the indicated dry seasons of the year very closely correspond to the times that the Earth is receding from, and the indicated wet seasons to those during which the Earth is approaching, that planet. It is found, then, that, in general, a year is indicated to be dry or wet according as the planet Jupiter comes in conjunction with the Earth in the first half, or in the last half of the year; as in the former case, all the recession from, while in the latter case all of the approach towards, that planet would be included within the year.

The time of sunspot maximum would thus correspond to that in which the planet Jupiter comes in opposition * with the Earth about the middle of the year, and the time of sunspot minimum corresponds to that in which it comes in conjunction with the Earth about the same time. Thus, in the sunspot maxima of 1883, 1871, 1860, 1848, 1837, the times of Jupiter's opposition were July 6, July 3, July 27, July 23, August 19, respectively, and in the sunspot minima of 1878, 1867, 1856, 1843, 1833, the times of Jupiter's conjunction were July 24, August 25, September 26, August 15, October 23, respectively; all of which are not far from the middle of the year except the last.

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*See foot-note, p. 67.

51. *The Maxima and Minima of the Planetary Connective Variations and their Causes.*—Before discussing a possible explanation of this, let us glance once more at the figures of Table III. Taking the indicated dry season of 1840 and adding its monthly values together they are found to aggregate 539, which sum is placed over the last monthly value of that season. The same is done with the succeeding wet season and with each following season in succession. In 1851 the mimimum seasonal sum of 266 is obtained,after which these gradually increase to a maximum of 554 in 1861, decrease to a minimum of 324 in 1872, increase to a maximum of 575 in 1882, decrease to a minimum of 277 in 1891, and so on. A moment's consideration suffices to show that the cause of these seasonal maxima and minima is the relative bunching and scattering of the four planets. If the four planets were all in the same longitude, the Earth would recede from, or approach towards, them all at the same time, and the aggregate value of a dry and of a wet season would then be a maximum. But if the planets were so evenly distributed around the Sun that the recession upon one side of the Earth was just balanced by the approaches on the other, then the aggregate value of a dry or a wet season would be the smallest possible.

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Now two of the three instances of this bunching together of the planets, and consequent maximum seasonal values, so far back as the table extends, closely correspond with the sunspot maxima of 1860 and 1883, both of which, it appears, were remarkable for the extent and number of the solar spots. A regular connection between the sun-spot maxima and the seasonal maxima could not be maintained, however, for any considerable period of time, as the periods of the two are not commensurable, that from sunspot maximum to maximum being about eleven years, while that from seasonal maximum to maximum is about nineteen years, being Jupiter's mean synodic period with the other three planets (chiefly with Saturn).* Now although the simultaneous occurrence of the sunspot maxima with the seasonal maxima, or comparative bunching of the planets on one side of the Sun in the two cases mentioned, is, no doubt, a chance coincidence, yet the more than ordinary spotted area of the Sun at these times could not reasonably be supposed to have the same chance origin.

52. *The Maxima and Minima of Sunspots and their Causes.*—What, then, is the significance of this bunching together of the planets at these extraordinary sunspot maxima? In the light of the connective theory, its significance is clear. Each of the planets is joined with the Sun by a primary connexion; and when the planets are nearly all in the same longitude, their

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* If, instead of considering the density of the planetary connexions to vary with the masses of the planets, or, which is nearly the same thing, with the *cubes* of their diameters, we had considered them to vary as the *squares* of their diameters, each of the several planets would then have a measurable value, and a much closer correspondence of the seasonal maxima to the sunspot maxima would have been obtained; and all the other correspondences would also remain practically unchanged. But as no sufficient reason could be assigned for such density values, they were, of course, abandoned.

solar connexions are aggregated upon one side of the Sun. The connective atmosphere of the Sun would, therefore, be more elevated upon that side. The heated vapor of the Sun would thus be enabled to ascend to a greater height, at which it would cool and descend more rapidly, and so form spots upon the Sun's surface. When the planets move out of conjunction, to an approximately equable distribution around the Sun—a movement which requires several years—the solar atmosphere (so far as the planetary connexions are concerned) would be reduced to about the same general level, and but little vapor could ascend sufficiently far to cool and condense, and thus descend to form spots.

That something about like this is really the mechanism of sunspot formation is abundantly verified by the researches of nearly all investigators of this subject. Mr. J. Norman Lockyer quotes from Dr. Peters and Rev. S. J. Perry to show that sunspots almost invariably commence life as little dots, which accumulate in larger and larger groups until full spot maturity is attained, usually in five or six days; and that the last act in their history is their invasion and extinction by faculæ. These faculæ are enormous upheavals of heated vapor which occur only in the neighborhood of spots and invariably arise subsequently to their appearance. In other words, a facula is the fire and vapor of a burning sunspot. Mr. Lockyer says. "We can see that it is the most natural thing in the world to suppose that in an atmosphere like the sun's, seeing that there is enormous radiation and therefore cooling at the exterior, there must be a descent of solid particles into the interior heated region. Now can we associate this with spot phenomena?

"Yes, we can, and we are absolutely driven to it.

We have already seen that the spot, when it travels over the limit, is a hollow. We also find when we examine a spot with the spectroscope that certain vapors get very much denser, as if they were being crushed together into a certain limited region either by an upthrust or a downfall. Which? Well, the spectroscope answers that question for us perfectly, because it shows that the vapors are absorbing, and therefore that they are cooler than the photospheric material immediately underlying them, and that they have not an excess of radiation, as they would have if they came up from below; the spectroscope then certainly justifies the view that a spot is really the result of a downrush; the vapors there are *cooler*, as they should be if they came from a cooler place; they are *denser*, as they should be, if they are descending rapidly into a place which is more or less confined; and, more than all, the change of the refrangibility of certain lines enables us to determine roughly the rate at which these descents take place. A very common velocity is thirty miles a second—not thirty miles a minute or thirty miles an hour, but thirty miles a second."* Elsewhere he also states: "Above latitude 30°, as a rule, we have no spots, because * * the atmosphere is of lower elevation, so that there is not sufficient height of fall to give the velocities required to bring down the material in the solid form."† In fact, there could not possibly be more direct and valuable evidence in favor of the theory here advanced.

But how are we to explain the sunspot minima which, it will be observed, do not scarcely in any case coincide with the minimum seasonal values, and also

*Nature, XXXIII, 470. †Nature, XXXIV, 255.

such sunspot maxima as that of 1871, which coincides with an actual seasonal minimum, or a state of nearly equable distribution of the planetary connexions round the Sun? We have already observed that the giant planet, Jupiter, practically determines the wet and the dry seasons, as well as the wet and the dry periods of years; and that, for a period of over fifty years, the times of sunspot maximum closely coincide with the times this planet comes in opposition with the Earth about the middle of the year, and the times of sunspot minimum coincide with those in which this planet comes in conjunction with the Earth about the middle of the year. Now, it is a generally admitted fact that the Sun itself is but a greater planet revolving slowly round some distant central body. Let us extend our theory, or, rather, let us extend its application, and regard the Sun as primarily connected with its sun, just as the planets are with itself. The material connexion of the Sun with its parent sun (as well as with the other important members of this greater system), would reasonably be more dense and voluminous than any of the planetary connexions; also, it would lie about in the plane of the solar equator for precisely the same reasons that the planetary connexions lie in about that plane. About every twelve years, therefore, the primary connexion of Jupiter and the Sun's primary connexion would coincide, and so form the comparatively elevated atmosphere upon one side of the Sun, which, as has just been seen, would facilitate the rapid formation of sunspots. And the fact that maximum sunspots occurs when Jupiter is on the opposite side of the Sun, from the Earth, in the middle of the year, points to the conclusion that the solar connexion lies in the direction of Jupiter at that time, and that the Earth passes through it in December and January.

53. *The Zodiacal Light and its Connection with the Sunspot Periods.*—Have we any evidence corroborative of this conclusion? We are so fortunate as to be able to present what appears to be a splendid and incontrovertible corroboration of it in the phenomenon of the zodiacal light. This phenomenon, hitherto inexplicable, interpreted by the connective theory, is nothing else than the Sun's connexion with the central parent system of which the Solar System is an immediate member; and it extends precisely in the indicated direction.

Regarding the zodiacal light, the peculiar misconception almost everywhere prevails that it is lenticular-shaped and extends equally all around the Sun's equator, or, at least, in two opposite directions from it. But that it extends only in one direction from the Sun is clearly shown from the fact that, for about six months of the year (from about August 1 to January 31), it is seen in the east just before daybreak, and that, for a somewhat longer season (from the end of October to about the middle of June), it is visible in the west after sunset. So that for about eight months of the year it is visible only in the evening *or* in the morning, that is, on only *one side* of the Sun; in the month of July, it is not visible at all, being then behind the Sun; and, in November, December and January, or while the Earth is passing through it, it is visible both in the evening and in the morning of each day. And, moreover, just before the Earth enters it in November it is observed to attain its greatest brilliance in the east, and just after the Earth passes out of it in January, it attains its greatest brilliance in the west.

If the light really extended equally in all directions from the Sun's equator, or even in two opposite directions from it, why should it not be visible in the month of September, for example, after sunset as well as before daybreak? One recent authority answers: "The reason it can not be well seen in the summer and autumn evenings is, that in our latitudes the course of the ecliptic in the southwest is, during those seasons, so near the horizon that the light in question is extinguished by the great thickness of the atmosphere through which it has to pass." But does he not forget that the same great thickness of the atmosphere would preclude its appearance in the southeast in the morning as well as in the southwest in the evening when in the same paragraph he states that "it may also be seen rising from the eastern horizon just before daybreak in the summer or autumn."*

The following extracts are from a memoir on *La Lumière Zodiacale*, by P. Marc Dechevrens, S. J., who has made at Zi-Ka-Wei, near Shanghai, China, regular observations of the zodiacal light from September 1, 1875, to September 1, 1879:

(*a*). "The observatory stands in the middle of an immense plain about twenty-five miles from the sea, and in no direction is its horizon broken by the slightest irregularity of the country; moreover, the observatory is isolated and the few neighboring buildings do not render the air impure or interfere with the most delicate astronomical observations.

(*b*). "When its two branches (the east in the morning, the west in the evening) have the same length—not exceeding 80° or 90°—the zodiacal light assumes the same shape on either side of the horizon; it is that of a lance-head or of half a lens a little flattened. But when its length reaches 90°, 100°, and beyond, it is rather a long band of light of nearly constant width, whose splendor does not sensibly diminish even to its extremity, which it is frequently difficult to find among the brilliant stars. Sometimes near the horizon the band appears as if it were to be enwrapped near its base in an envelope yet more luminous.

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* Newcomb's *Popular Astronomy*, p. 416.

(*c*). "The luminosity always appears quite steady and motionless. Its color is always pure white, like to the Milky Way. * * *

(*d*). "The luminosity participates in the apparent diurnal motion of all the stars; this fact has been noticed by all who have observed the phenomena and is opposed to all theories which designate the terrestrial atmosphere as the place of the zodiacal light.

(*e*). "The general features already described are not derived alone from the observations made at Zi-Ka-Wei; they have been admitted by the earliest observers and are generally adopted by all savants.

(*f*). "The following details, undescribed as far as I know by any author, stand out prominently in the whole series of our observations.

(*g*). "The two branches of the zodiacal light, the eastern in the morning, the western in the evening, neither appear on, nor disappear from, the horizon at the same time; but their maximum of elongation takes place at the same moment.

(*h*.) "The total duration for their appearance is six months for each branch.

(*i*.) "The first luminosity in the east appears in the early days of August, and the last dies out at the end of January. On the western side the zodiacal light is first observed about the end of October, and entirely disappears only in June.

(*j.*) "Thus, during November, December, and January, in the morning before dawn, and in the evening after twilight, there can be viewed these two luminous bands among the stars, making in that part of the sky an angle of nearly 60° with the Milky Way, whose brightness and purity they rival—especially in parts nearest the sun.

(*k.*) "The eastern branch (in the morning) slowly elongates from its first appearance; on the contrary, the western branch (in the evening) rapidly develops, and in a month can reach its maximum of elongation. Inverse phenomena prevail in its disappearance; that is to say, the morning luminosity grows faint in a short time after the epoch of its greatest elongation, while in the evening the opposed luminosity varies very slowly, and disappears almost insensibly.

(*l.*) "Owing to doubts expressed by savants regarding isolated observations showing an elongation of 90° and more, the following, frequently confirmed by my coadjutors, are given: 1875, November 28 (morning), 100°; December 21 (evening), 120°; 24th (evening), 123°; 25th (morning), 140°; the night of December 24-25, the phenomenon embraced three-quarters of the ecliptic; 1877, December 1, 3, 4, and 7, the band of light reached to the Milky Way, passing between the Pleiades and Aldebaran, (nearer the first stars than the latter one); then losing itself in the Milky Way, the luminosity had yet enough brilliancy to cause us to think that it prolonged itself even to the other edge of the starry zone. The sun being then in the 251st degree of longitude, the arc of the ecliptic covered by the luminous band was not less than 185°. This observation was made *four* times. A gap of about 65° separated the morning and the evening branches so that the total amplitude was then about 295°. The observations made by M. Eybert in 1873 (published by Heis, in Münster) during a voyage from Buenos Ayres to Cape of Good Hope, agree perfectly with these. He noted December 8 (evening), in latitude 20° N., an elongation of 184°, and (morning), the other branch showed an elongation of 176°, so at that time the whole ecliptic was covered by the luminous band.

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(*m.*) "As to the brightness of the two branches the maximum—not coinciding with the greatest elongation—was observed in November for the eastern and in February for the western branch."[*]

Through all this description there appears to run in the mind of the observer the idea that there are two separate branches of the zodiacal light; whereas according to the description itself, there can have been but the one branch. The side of the Sun which becomes first visible in the morning and from which the zodiacal light projects, say in September, is the opposite side to that which last disappears beneath the horizon in the evening and from which the opposite branch of the luminosity would be seen to project if there were such a branch. But no such branch has ever been seen at that time. It is equally obvious also that, if, for simplicity, the Sun be regarded as stationary on its axis, the side of it which first becomes visible in the morning from the first of August to the last of October and from which the morning branch is seen to project, is precisely the same side which last disappears in the evening from the first of February till June and from which the evening branch is observed to project. This follows so manifestly from the Earth's motion round

[*] *Report of the Chief Signal Officer U. S. Army 1881*, pp. 908-9.

the Sun that it were superfluous to dwell upon it further. Therefore, according to the observations from July to November and from January to July, the zodiacal light is seen to project only from one side of, or rather in one direction from, the Sun; and so there could be predicated from these observations but one branch of the luminosity. Then as to the three months during which the luminosity is visible both in the evening and in the morning of each day, nothing seems plainer, if the luminosity occupies an angular space of some 90° on one side of the Sun, than that when the Earth passed into the angular space thus occupied, the luminosity would become visible on both sides of the horizon. Paragraph (*k*) of the foregoing description really proves that this is the case. The rapid development of the western branch, occupying only a month from its first appearance to its maximum elongation, finds its only explanation in the passage of the Earth suddenly into the midst of the luminosity; and the equally rapid decadence of the eastern branch from its maximum elongation to its extinction is explicable only by the sudden passage of the Earth out of the midst of the luminosity.

We have thus somewhat elaborately discussed this phenomenon on account of its great importance in the theory here advanced, and also on account of the misconception alluded to, which, it appears, every writer on the subject inculcates regarding it. In the light of the connective theory, it furnishes the almost complete explanation of the sunspot periods, compared with which the configuration of the planets alone play but a very subordinate part. The maxima of sunspots occur when Jupiter's primary connexion is about in the last stage of its coincidence with the "zodiacal light," or, as we may now be permitted to term it, the Sun's primary connexion; which, at the present time, and for about a half century back, would happen when that planet is on the side of the Sun where the Earth is in January and February. In the first part of the period of coincidence of the two great connexions, the solar vapors and gases would be ascending, so that the maximum of descent of the cooled material would occur in the latter part of that period, or even just after coincidence was over and the elevation of the solar atmosphere on that side was at a maximum rate of reduction down to the general average. And the times of the minima of sunspots (though thus less regularly determined) would, in general, occur when the two chief connexions were as far apart as possible, or when Jupiter occupies that side of the Sun where the Earth is in July and August. It is very obvious also that the maxima and the minima of the spots would not be suddenly, but slowly and gradually attained, as the two connexions (modified, of course, by the other connexions, also,) moved gradually, in the course of five or six years, into, or out of, coincidence.

These theoretic deductions appear to be strongly corroborated by actual observation. Assuming for the present (what will shortly be more fully shown) that the long streamers or rays of the corona are really the Sun's connexions with the planets and other heavenly bodies, the following quotation clearly shows the connection of the spots with the movements of the connexions: "The coronal streamers follow the spots—by which I mean that the corona and coronal streamers put on their greatest intensity, according as the spots have moved nearer to the equator. When we have the minimum sun-spot period, you can hardly call that equatorial extension a streamer at all, because it is so dim."[*] When the spots move nearer to the equator, it is about the time of maximum sunspots, and this, Mr. Lockyer tells us, is the time when the coronal streamers put on their greatest intensity, in precise accordance with the theory.[†]

54. *Explanation of Anomalous Sunspot Periods.*—But still this explanation is imperfect; for, if we go back as far as reliable sunspot records extend, we find that Jupiter no longer comes in opposition with the Earth at maximum sunspots in July and August, but rather towards the end of the year. Thus, in the sunspot maxima of 1829, 1817 and 1804 the times of opposition of Jupiter were in December, December, and November, respectively; while in the maxima of 1790 and 1779 they come back again as far as September. We observe, however, that the three former sunspot maxima were of little more than half the average extent.[‡] This goes still further to show what reasonable probability has already suggested, that the solar connexion is a compound one with the different bodies of the parent system, which separate from one another owing to the proper orbital motions of some of them around the central body of that system; just as the Earth's primary connexion sometimes coincides with its secondary connexions with the inner planets, and then separates from them again to various angular distances.

We are again able, in a degree, to corroborate this by observations of the zodiacal light. For, as we go back from recent years, we observe that the elongation of this luminosity continually diminishes, in complete accordance with this view of its greater angular diffusion in past years.* The same consideration also furnishes a very probable explanation of the remarkable period, 1672–1713, during which scarcely any sunspots appeared at all.† For it seems quite possible that the solar and planetary connexions may have maintained a state of changing equability of distribution all around the solar equator during that period.

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[*] J. Norman Lockyer, *Nature*, XXXIV, 44.

[†] The various peculiarities of sunspots, such as their equatorial drifting and their greater angular velocity in the lower latitudes of the Sun, will be discussed further on. See Arts. 156 and 157.

[‡] See Prof. B. Stewart's diagram, *Nature*, XXXIII, 252.

This is not the first time that the movements of the planet Jupiter have been suspected to bear a definite relation to the sunspot periods. But owing to the disparity of the two periods—that of Jupiter being about 11.86 years, while the sunspot cycle is about 11.2 years—the idea was abandoned. The changing positions of the solar connexion and of its several components, however, appears to overcome this difficulty.

55. *Existence of Invisible Heavenly Bodies.*—But another difficulty arises in connexion with this view, viz., If the Sun's primary connexion, or its components, are continually changing position, the bodies to which these connexions extend ought also to change positions in exact correspondence with these connexions. Yet no such change of position of any heavenly body is observed to take place in that or any other quarter of the heavens; although, from the nature of the case, the bodies to which such connexions extend, would probably be quite equal, or even more than equal, in magnitude to the Sun itself.

This is apparently a very serious difficulty; but the connective theory itself, when applied to the various

*See O. T. Sherman's diagram in *Nature*, XXXIII, 595.

†See *Nature*, XXXIX, 469.

stages of cosmical evolution in detail, furnishes a probable explanation of it. We must here anticipate the results of this application and postulate, with Lambert, the existence of dark heavenly bodies; and not only their mere existence, but their far greater number than that of the bright ones. This view does not indeed fall in with the views of most recent astronomers; but there really is no serious objection whatever urged against it. According to the connective theory, the sidereal sphere is one system every member of which revolves about a common center. This system is made up of sub-systems, and so on down to probably twenty or thirty successive systemic orders; and each of these systems has a common center of motion for its own members, and has also, as a whole, the proper motion of each larger system in which it is included. But of course all of these motions which would be visible to us from stellar distances would be of a comparatively vast magnitude and consequently of extremely small angular velocity.

And further it is also a deduction from the new theory that the Sun, *e. g.*, is continually cooling; that the spots which we observe upon its surface are the inchoate attempts at crust formation; that further cooling will increase the spotted area; and that eventually a solid crust will thus be formed over the entire surface of the Sun, so as to render it, at least to a distant observer, a cold and dark body. It is a similar deduction also that every member of the solar family was once self-luminous, as the Sun is now, but that, by cooling and similar crust formation, they have become cold and dark, as the Sun in all probability will be. Now (regarding the asteriods as one planet), there are in the Solar System nine principal and twenty smaller regularly derived bodies; and of these twenty-nine bodies all are dark except—shall I say one? Not exactly, for the new theory teaches that, were the over-powering effects of sunlight extinguished, at least two other bodies (Mercury and Saturn) would be self-luminous. Here then are only three bodies out of twenty-nine, or about one in ten, which are self-luminous. Yet the same reasoning exactly applies to any other system of the sidereal sphere, of whatever order just as well as to the Solar System. So that, of that system from which the Sun was immediately derived, the Sun itself may be the only self-luminous member of sufficient magnitude to be visible to us. The central body or sun of that system from whose bosom they originally came is just as likely to be dark to us as any other member; but even if it were bright—even if it were one of the splendid group of first magnitude stars which lies in that direction and which includes, not only the most brilliant, but also about half of all such stars in the whole heavens—we are not prepared to say with much probability whether, under the circumstances, the light, even from such a star, reflected by the darkened planetary bodies derived from, and revolving around it, would render these bodies visible to us or not. At least it does not seem improbable that the angular diffusion of the Sun's primary connexion, which our investigations appear to predicate, are due to the orbital motions of many darkened sister suns, which revolve at angular velocities different from that of the Sun around a common orbital center.

56. *Sidereal Connexions and Sunspots.* — Still another difficulty has no doubt occurred to the reader. The zodiacal light, or the Sun's primary connexion, extends

from that luminary in one direction, but the line of greatest sidereal extension is almost exactly in the opposite direction; and since the greatest amount of solar connexions must lie in this last direction, how can it be that, when Jupiter's connexion coincides with it, there is a minimum of solar atmospheric elevation and consequently of sunspots? The reply to this is that it is not the *quantity* of the connexions which affects the elevation of the solar atmosphere so much as the *kind*. The sidereal connexions on the one side are about all with distantly related bodies. They have been sifted again and again from the *secondary* connexions of the successive orders of the sidereal subsystems down to the Solar. At every sifting the stronger components of the connexions were, in all probability, left behind, and the more superfluous, least used, and weaker components taken up. So that when the Sun, as it separated from its parent sun, took up its due proportion of the already more than thrice-blown sidereal connexions of that body, the very faintest, weakest, and literally most useless components must have fallen to its share. And these are the connexions which, though comparatively great in quantity, owing to the comparative greatness of their number, extend from the Sun in the opposite direction to that of its primary connexion. The latter, on the contrary, is in its pristine strength, and together with the next most important connexions in this respect (with the exception of the primary connexions of the planets), viz., the secondary connexions with the Sun's sister planets, it serves as a support in and around which the surrounding solar atmosphere may collect and up-climb. The Sun's primary connexion is also in a continual state of *strain*, owing to its function of restraining the Sun in its orbital motion, and this strain would, of itself, serve to elevate the solar atmosphere within it; whereas, the sidereal connexions have no such restraining function, are too refined even to transmit heat-motion, and serve only to convey a faint amount of light, and even this, in all probability, consisting of the most refined components of light-motion. All this is also implied in the application of the connective theory to the cosmical distribution of light and heat, and to the aerial and oceanic tides, and will receive further elucidation when these phenomena are discussed.

57. *The Connective Variation of the "Zodiacal Light" and Other Portions of the Sidereal Factor Upon the Earth.*—This seems to be the proper place, also, for saying a few words further about variations of the Earth's connexions with the Sun's primary and sister planets as affecting the connective substance in our atmosphere. These variations have already been included in the sidereal factor; but their consideration in somewhat greater detail may not be uninstructive. Did we know the actual magnitude of the Sun's primary and sister planets, we might, on the basis already employed, find the limiting value of the variations of its connexions upon the Earth. But this we do not know, and it so happens that, for the present purpose, it is not necessary for us to know. For, as already stated, the variation arising from this cause has almost precisely the same period as the sidereal variation, and the two are, at the present time, directly antagonistic because their sources are in diametrically opposite points of the heavens. In effect, therefore, it amounts to just the same as if the sidereal factor had been found less powerful, or the solar factor more powerful, by the amount of the factor now considered. The

annual results and indications of Table III are wholly unaffected by it for reasons already stated. And, at present, it appears to be of theoretical importance, chiefly as corroborating the Flood legends already referred to. Since the Sun's primary is presumably many times larger than the Sun itself, the value of the variation of this component can not be much less than that of the solar factor. Indeed, if we should assume that the former was a thousand times as large as the latter, so that the Sun's primary connexion would be a thousand times more massive for equal lengths than the primary connexion of Jupiter, then the value of this factor would, on the basis employed, be no less than about fifty times that of the solar factor. Now, as the Sun very slowly revolves around its primary, this factor, instead of being in direct opposition with the sidereal factor, would eventually be brought into conjunction with it. And as the latter, judging from its effects, must be superior in value to both the other factors, still more tremendous floods might characterize such conjunction than in the case of the conjunction of the sidereal and the solar factors; and even the conjunction of all those factors, so far as can be seen, seems not improbable. But as we do not know at what angular rate the Sun performs its proper orbital revolution, we are quite unable to say at what time any conjunction involving this factor (or rather the main part of it) would take place.

We have now considered the last remaining significant factor of the connective variation in our atmosphere. The almost geometrically diminishing massiveness of the connexions with the arithmetically diminishing relationship of the bodies they connect (owing to the smallness of the derived, as compared with the primary, bodies) would render the value of any individual connexion between bodies related beyond the second degree of kinship, too small to affect perceptibly the results already obtained.

58. *The Solar Corona.*—Since, in the crepuscular light of the dawn and the twilight, we are able to observe the Sun's primary connexion, or at least a portion of what we suppose to be the Sun's primary connexion, extending outwards to its parent system, the question arises—Why are we not able to observe the planetary connexions at the same time? The answer is that the planetary connexions are supposably much less voluminous and massive than the solar connexions; and that, consequently, the former, if visible at all, would be so only in the immediate neighborhood of the Sun, where, perhaps, extremely rare gaseous constituents arising from the Sun itself might contribute to their visibility. But, at the time the "zodiacal light" is observed, the immediate neighborhood of the Sun is, of course, below the horizon.

There are, however, certain rare occasions when the face of the Sun is hid from, while its immediate neighborhood is still exposed to, our view; and these occasions furnish us the strongest possible evidence confirmatory of the existence of these connexions, as above surmised. When the Sun is eclipsed by the Moon, rays, or streamers, are seen to project outwards from the solar equator in various directions and to various distances. Prof. Langley states that, in the eclipse of 1878, the streamers could be traced to a distance of fourteen millions of miles. But, if the effects of foreshortening were taken into consideration, their real extension would no doubt be found to be much greater even than this. These streamers appear perfectly steady and permanent so long as the circumstances permit them to be seen at any one time; but between one eclipse and another, they vary their positions, so that in any two eclipses they are not alike.

What are these rays or streamers of the Sun's corona? The most eminent students of solar physics tell us frankly that they do not know. "The sun is doubtless surrounded by a gaseous atmosphere of a certain extent, but there are a number of reasons why the corona should not be regarded as a prolongation of this atmosphere. A gas even a hundred or a thousand times lighter than hydrogen, at the height of the corona, would, at the sun's surface, be heavier than metals; a state of things which spectroscopic and other observations show can not be the true one."* The same scientist also speaks of "the relative permanency of the coronal forms during several weeks," and states, "If the forces to which the corona is due resides in the sun, the corona ought, of course, to revolve with it; but if the corona is produced by causes extraneous to the sun, it may be otherwise." The fact is, that the corona does not revolve with the Sun, as its "relative permanency during several weeks" indubitably attests. But that it has a peculiar revolution of its own, the following extract from an excellent authority sufficiently demonstrates: "If the photographs taken during eclipses in the past twenty years are compared with each other, it will be seen that the corona varies in a regular way with the state of the sun's surface, although there are irregular minor changes. At the sunspot minimum, the corona is much more regular than at the maximum. At the maximum there is practically no regularity at all; the long streamers go up sometimes in one direction and sometimes in another, and this last year (1882), near the sun-spot maximum, there was absolutely no symmetry in the appearance of the corona." * This (as well as the quotation from Lockyer, Art. 53) is in precise accordance with the theoretic conclusion just discussed regarding the relative aggregation of the principal connexions at maximum sunspots and their more equable diffusion on all sides of the Sun at sunspot minimum.

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* Dr. Huggins, in a lecture at the Royal Institution, Feb. 20, 1884.

By the new theory, the coronal phenomena are understood at a glance to be nothing more than the Sun's connexions with the heavenly bodies. The solar connexions with certain bodies would, at times, owing to the varying positions of these bodies, lie in about the same direction from the Sun, and thus would become visible to us as a "ray," or "streamer," or "radial glory." The visibility could not, however, extend very far, as the connexions diverge as they proceed outwards from the Sun, and thus the density of the "ray" is diminished. It also becomes intelligible that the positions of the "streamers" do not vary during the time of an eclipse, but that, during the far greater period between eclipses, remarkable changes in their positions take place; all of which observation shows to be the case. Another most significant feature is described by Mr. Lockyer as follows:

"At both the poles, north and south, (of the Sun) there is a wonderful curving, right and left; this outcurving having been one of the most exquisite things which it is possible to imagine.

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* Prof. Edward S. Holden, *Account of the Progress in Astronomy, in the year 1883.*

"There is further evidence indicating that the equatorial extension on the photograph may only, after all, have been a part of a much more extended phenomenon, one going to almost incredible distances—considering it as a solar atmosphere—from the sun itself.

"It has already been stated that at that eclipse one observer took extreme precautions to guard his eyes from being fatigued by the light of the inner corona, which sometimes is so bright that observers have mistaken it for the limb of the sun itself. What this gentleman, Prof. Newcomb, did was to erect a screen which covered the moon and a space 12′ high around it. The result was, that as soon as he took his station at the commencement of totality, he saw a tremendous extension of the sun's equator on both sides the dark moon, the extension being greater than that recorded in the photograph. It does not follow that the photograph gives us the totality of the extension; it may be that the extended portions may have been so delicately illuminated, that they would not impress their image on the photographic plate in the time during which that plate was exposed, or that the light itself is poor in blue rays. So considerable was this extension, amounting to six or seven diameters of the dark moon, which practically may be taken to be the same as that of the sun behind it, that Prof. Newcomb had at once suggested to him the zodiacal light." "The drawing made in 1867 gives us the same result. We again get the equatorial extension east and west, and the wonderful outcurving right and left from the sun's poles."*

As all the members of the Solar System, and also in all probability the Sun's primary and sister systems lie very nearly in the plane of the Sun's equator, this "tremendous extension of the corona in the direction of the solar equator," as well as "the wonderful outcurving right and left from the sun's poles," becomes at once intelligible by the new theory, and serves moreover as a wonderful corroboration of it.

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*Nature, XXXIV, 42-3

By this theory all other bodies of our system have a corona as well as the Sun. But as the latter is a central body and vastly larger than any of them, its corona would therefore be far more dense, and so more likely to be visible to us. It may be mentioned here that Mr. W. H. Pickering of Harvard College, in attempting to photograph the solar corona in full sunshine, although his plates showed several corona-like markings, yet regarded them as clearly not due to the true corona *because similar markings were found in front of the Moon.** Of whatever value this discovery may eventually prove in the light of new facts, it is plainly what the new theory leads us to deductively, as the Moon's comparative nearness would perhaps make its connexions visible to us in spite of their much greater rarity.

59. *Relative Visibility of the Various Solar Connexions, and their Real Directions as Viewed in the Rays of the Corona.*—But a further question arises—If some of the planetary connexions are visible at the time of a solar eclipse, ought not the solar connexion, or the zodiacal light, owing to its greater density and prominence, to be much more conspicuously visible, and to a vastly greater distance? To which the reply is, that while the solar connexion would for this reason be more conspicuously visible—and, in general, very probably is so—it would not reasonably be expected to

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**Nature*, XXXIII, 42.

be seen to a much greater distance owing to the much greater amount of sunlight in the air during an eclipse than at the time it is viewed as the zodiacal light.

As the real position-angles of the coronal streamers have not in the past been very systematically observed, it is extremely doubtful that the real positions of the planets could be deduced from the apparent positions of the coronal rays observed in past eclipses. But one eclipse, that of July 29, 1878, observed on the summit of Pike's Peak, Colorado, from the minute details of it given in the Report for 1880 of the Chief Signal Officer, U. S. Army, who, with several other distinguished observers, was personally present, appears strikingly to show the two principal connexions in opposition with each other (it being the year of sunspot minimum), the solar connexion extending outwards in the background beyond the Sun, and that of Jupiter extending in the direction of the Earth, the two planets being then almost exactly in conjunction. These two great streamers and their apparently direct opposition to one another, are the only prominent characteristics of the corona observed on the Peak itself, and they are the most prominent characteristics in the twenty-seven sketches of the eclipse at different places which accompany the Report. "The positions of the rays or beams seen by the different observers all agree with each other within the limits of accuracy of the sketches. However various may have been the impressions received by the different observers, yet each failed to see and record any material change during the two or three minutes that the corona was visible to him. We thus have twenty-five little intervals of two or three minutes each, many of which overlap each other so that in effect there is a continuous line of testimony to the permanence of the appearance of the corona." (p. 922).

A casual glance at the streamers (as observed on the Peak by H. H. C. Dunwoody, for instance), does not, indeed, give the impression that one of them extends towards the observer and the other beyond the Sun; for both apparently extend at right angles to the line of sight. But this would obviously be the case, however small the inclination to the line of sight (the Earth was $4\frac{1}{2}°$ in advance of Jupiter at the time, and, it being about 4 o'clock P. M., local time, Jupiter's connexion would therefore appear to extend from the upper left-hand corner of the Sun), for the same reason that the rays of a lighted candle, which really enter the nearly closed eye of the observer, appear to him to extend from the flame in opposite directions almost at right angles to their real direction. It is, therefore, a matter of some difficulty to determine the real directions in which the coronal streamers extend; and too much, perhaps, is assumed when the two principal connexions in the sketches alluded to are regarded as in opposition. But the prediction is here ventured that, with more systematic observations in the future with respect to this special subject, the directions of the coronal rays will be found to coincide exactly with those in which the bodies lie to which they respectively extend; and two of these bodies will be Jupiter and Saturn, while one or more will lie beyond the planetary limits and belong to the Sun's parent system.

60. *Summary of the Results From this Inquiry.*—We have now completed the inquiry into the connection between the planetary motions and the phenomena of precipitation in our atmosphere, spots on the Sun, the zodiacal light, the solar corona, etc., and while we

have met with no evidence whatever, going to disprove such connection, we have found many valuable evidences which go to show that such a connection really exists. The principal portions of these evidences may be here briefly recapitulated.

In the first place, it was assumed that the planets were connected with the Sun and with one another by material cords or connexions, and the purpose of the inquiry was in part to prove or disprove in a degree the actual existence of these connexions; because if their actual existence were proved, the connection in question would obviously be at once established, and if their existence were disproved, the whole inquiry, which was based on their supposed existence, would fall to the ground.

The relative variations of the supposed connective substance in the case of each principal planet of the Solar System were then computed, and those bodies which, other things equal, produced comparatively insignificant variations, were disregarded. Computing the variations for each of the remaining bodies for each month of a period of more than half a century, and obtaining the algebraic sum of the results, both for each month and for each year, the first evidence in favor of the existence of such inter-planetary connexions was brought to light in the fact that the periods of years during which the quantity of the connective substance in our atmosphere would be below the average and above the average, were found to be almost precisely parallel with the periods of years during which the area of black spots on the Sun was below the average and above the average respectively; the chance occurrence of such a parallelism for so long a period on any other basis being deemed improbable in the highest degree.

The second evidence for the existence of material inter-planetary connexions was the equally exact coincidence of the periods during which the connective substance in our atmosphere would be above the average with those periods during which the auroras and the quantity of atmospheric precipitation were actually observed to be in excess of the average; and also with those in which the barometric pressure was observed to be below the average; the most reasonable view being that a considerable excess of the connective substance in our atmosphere would cause a corresponding excess of auroras (which would be merely streams of the connective fluid itself), and of atmospheric precipitation (which would be simply a condensed form of the connective fluid); the diminution of pressure accompanying the excess of connective substance being due to the high elevation, or region of diminished attraction of gravity, which the rarer atmospheric vapors are, in consequence of the more elevated connective atmosphere, enabled to attain.

The third evidence supporting the material planetary connexions was the correspondence of the deductions derived from them to the views of modern astronomers, according to which our world is situated considerably to one side of the center of the Sidereal System. Agreeably to this view, the connective substance would accumulate on the Earth while it was moving towards the point in which the greatest linear extension of the heavens from the Earth lies, and would be drained away while moving in the opposite direction. The former movement occurs in the first half of the year, implying, when necessary allowances are made, more than the average precipitation during our summer seasons; and the latter occurs in the latter half of the year, equally implying less than the average precipitation in our winter seasons—all of which is in accordance with actual observation.

The fourth evidence found in support of material planetary connexions was the simple manner in which the sunspot periods admitted of explanation by means of them. It was found that the sunspot maximum nearly always occurred when the great planet Jupiter was in a certain longitude, with respect to the Sun, or in the neighborhood of the great stars Aldebaran, Capella, Sirius, Alpha and Beta Orionis, Procyon, Pollux, and Regulus—all of which are of the first magnitude and form such a splendid galaxy as no other equal area of the heavens can nearly approach. Pushing the inquiry further, it was found that the vast luminous band called the zodiacal light extended precisely in this direction, and occupied the same heliocentric angle as the group of stars just named. It became evident, therefore, that the so-called zodiacal light was nothing else than the material connexions uniting our Sun with bodies not very distantly related to these stars and others in this neighborhood. And the sunspot maximum would be due to the aggregation upon one side of the Sun of Jupiter's primary connexion and the Sun's connexions with these bodies. For, by means of this aggregation of connexions on one side of the Sun, the solar vapors would be enabled to ascend to comparatively great elevations, where they would cool, condense, and fall to form the spots in exact accordance with the observations and deductions of all modern students of solar physics. This view was still further corroborated when it was found that the sunspot minima corresponded, with about equal exactness, to the times during which the planet Jupiter lay in the direction from the Sun opposite to that which it occupied at maximum sunspots.

And the fifth and last principal evidence in favor of the existence of material planetary connexions is that *we actually see them with the naked eye*, not only in the zodiacal light, but also in the streamers of the solar corona. It is possible of course that these streamers and coronal rays are not material connexions extending outwards from the Sun to neighboring heavenly bodies; but they certainly present the exact appearance which such material connexions would make on every occasion of their observation by us; and they certainly have remained for all these centuries up to the present time confessedly inexplicable on any other basis. And the same remark also applies to the sunspots, the zodiacal light, and the known variations of the numbers of auroras and the amounts of atmospheric pressure and precipitation.

61. *Possible Objections to the New Theory.*—These are strong, indeed, for all that have so far appeared to be contrary, incontrovertible evidences in favor of the connective theory. What now are the evidences against it? Will it be adduced as an evidence against it that the opposed force-theory has long been established and generally accepted? Perhaps so; but against such evidence argument is useless. The only hope of confuting it is in the increased intelligence and liberality which the human mind may eventually attain.

One apparently serious objection, and the only one which, so far as we have gone, seems to be conceivable, is the various effects upon terrestrial heat, light and gravitation, which the deduced various quantities of connective substance in our atmosphere might be supposed to predicate. Thus the solar connexion is probably as dense for equal volumes as any other which falls upon our planet. How is it, then, that on the side of the Earth upon which the connexion falls, the attraction of gravitation is not measurably increased, since it is upon the density of this connective atmosphere that that attraction is held chiefly to depend? (See Art. 24.) In other words, why does not an object weigh more during the day than it does during the night? Also, the enormous accumulations and drains caused by the variations of the predominant sidereal connexions—would they not also be accompanied by corresponding variations in the light, heat and gravitation manifested upon our Earth, since it is upon the quantity of the connective atmosphere that these phenomena also depend?

In reply to these objections, it may be stated first, that, as already intimated, the connective atmosphere of the Earth is made up of innumerable individual connexions—connexions not only with all the heavenly bodies visible to the naked and the telescopic eye, but also with countless others of which the eye or the telescope furnishes no evidence. It seems reasonable to suppose, therefore, that the density of an atmosphere thus constituted would not be affected by the addition or withdrawal of any one connexion, even of that with the Sun, to any sensible degree. Owing to the eccentric position of the Earth with respect to the celestial sphere, there would obviously be a greater number of connexions, and therefore a possibly denser connective atmosphere on that side of the Earth on which the greater portion of the sidereal sphere was situated. But granting that the connective atmosphere on one side would be very considerably increased owing to this cause, or a combination of similar causes, it is also true that the supposed change of density would take place slowly, and, as the movements of the free or reserve connective substance in our atmosphere is much more rapid, is, in fact, literally as quick as lightning, there would be ample time for this free connective substance to move from the side of greatest pressure to the opposite side, and thus continually maintain a very approximate uniformity of density on all sides of the Earth. Of course it is not implied here that *greater elevation* of the connective atmosphere does not occur upon one side of the Earth than upon the other. Such greater elevation of the connective substance (accompanied no doubt by greater aerial elevation) would be owing to the location of principal primary connexions on that side, and would, therefore, of itself, tend to equalize the distribution of connective density and pressure.

A further consideration is that the connective atmosphere itself does not revolve with the Earth in its diurnal revolution. It is, indeed, bodily carried along with the Earth around the Sun; but it is absolutely fixed with respect to its axial rotation. Therefore, an equable distribution of pressure or density, once attained, would be unaffected by an accumulation or drain from any particular direction.

If it be objected that the density (and consequently the functions) of the connective atmosphere, as a whole, changes, from time to time, with the variations of its connective substance, it may be replied that the connective atmosphere of the Earth is vastly more extensive than the limits either assigned or assignable to its aerial atmosphere. Thus the influx, or the efflux, of the enormous volumes of connective substance involved by the variations of the terrestrial connexions has a correspondingly inferior effect on the connective density. And another consideration in this respect is that an increase of connective pressure and consequent density above the normal, even if it did exist to some extent in particular localities, would quickly be relieved by precipitation of the surplus connective substance into some form amenable to the attraction of gravity, and therefore no longer contributing to the sum of that attraction. The converse of this is equally true. A deficiency of connective pressure and density would be relieved by transformation of previously precipitated forms into the original state. So that very probably no perceivable variation of connective density could exist in our atmosphere, owing to this cause.

But supposing that variations in the density and functions of the connective atmosphere did actually exist—that, for instance, the absolute effect of the attraction of gravity is really variable within tolerably wide limits—we might in turn become critical, and inquire how we could ever become conscious of such a variation. We never could detect such a variation by means of the balance, for very obvious reasons. And if it be replied that the variation might still be detected by means of the elastic strength of springs, or by means of muscular sense and strength, the inquiry at once occurs —Is any one really prepared to demonstrate that the elastic strength of springs, and even the energy of muscular action would not be affected in precisely the same manner as the attraction of gravity? May not every molecule of the spring, and of the muscle, and even of the perceiving brain, have a proper connective atmosphere of its own (as Helmholtz and others strongly suggest) upon the density of which the energy of their action depends, and the density and energy of which are in turn dependent on the density and energy of the general atmosphere?

62. *The Tests of the Connective Theory which yet Remain to be Considered.*—From every point of view so far obtained, the objections to the connective theory are seen to dissolve away into insignificance. No other objections can be imagined at the present time that could seriously be urged against it. Is the reader then, still unsatisfied with the credentials of the new theory? And, if so, how is it possible to convince him further of its genuiness and truth?

There are two ways still open in which this may be accomplished; first, the existing theory may be shown to be inconsistent with the principal phenomena within the province which it is supposed to govern; and second, these and all the phenomena of nature may be shown to be in exact harmony with the new theory. But to employ either of these methods in fullness and detail is very obviously quite impossible within the compass of these pages. The only further course in this case therefore appears to be a very cursory examination of a few principal phenomena with respect to both theories with the object of showing the merit or demerit of each. And, as the reader is no doubt extremely chary, and justifiably so, of accepting new views until every reasonable assurance of their correctness is given, this course will be adopted.

Perhaps, after all, a complete conviction of the relative correctness of the new theory can not be expected to follow from so incomplete a consideration of the facts. But if it can be shown that of *many* of the most important phenomena of cosmical evolution, the current theory furnishes not the slightest conceivable explanation, and that, by a *few*, it is squarely contradicted, while *all* of these phenomena are shown to be fully in harmony with the new theory—does it really seem unreasonable to expect that the superiority of the new theory over the old would then be generally conceded?

To prevent misconception, it may be remarked that the *old theory* here refers especially to the idea that light and heat and a "force" of gravity spread outwards from every body to indefinite distances in accordance with the law of inverse squares; and that the *new*, or *connective theory* refers simply to the idea of material, but highly tenuous and elastic, interplanetary connexions, and that in, and by means of, these, together with the connective atmosphere which they involve, the phenomena of gravitation and the transmission of heat and light are wholly manifested.

PART II.

OBJECTIONS TO THE THEORY OF GRAVITATION.

Every hypothesis is bound to explain, or, at any rate, not be inconsistent with, the whole of the facts which it professes to account for; and if there is a single one of these facts which can be shown to be inconsistent with (I do not merely mean inexplicable by, but contrary to) the hypothesis, the hypothesis falls to the ground; it is worth nothing. *Prof. Huxley.*

CHAPTER I.

NEBULAR ROTATION AND TRANSLATION.

63. *The Primal State of Matter.*—Let us begin with the most general cosmological conception involved in the nebular hypothesis—"that of a nebulous matter dispersed in masses throughout the immensity of the heavens." This appears to be the postulate of Kant, Huyghens, Sir W. Herschel, Laplace, and more recently, Herbert Spencer. It is not, however, the most general cosmological conception; for Anaxagoras, Democritus, Descartes, Newton, and, it seems, Sir W. Thomson, have believed that there primordially existed a universal homogeneous medium, or "primitive fluid," as Sir W. Thomson calls it—which certainly appears to be the true starting-point of cosmical evolution. But this

universal medium may be considered as a grander type of a systemic nebulous mass; and the same reasoning will then be applicable to both.

64. *Atomic Attraction and Repulsion.*—We shall discuss, then, a vast nebulous mass, employing it as the representative of any nebulous mass down to the dimensions of the Solar System. And, regarding the phenomena likely to originate in such a mass, we may examine here chiefly the views of Mr. Herbert Spencer, which also appear to be approximately those of the most eminent scientists on this subject.

"Given a rare and widely-diffused mass of nebulous matter having a diameter, say as great as the distance from the Sun to Sirius, what are the successive changes that will take place in it?" First, "mutual gravitation will approximate its mass;" and second, "the approximation will be opposed by atomic repulsion." Now here, right in the start, is something that seems very curious. The atoms *attract* one another and they *repel* one another at the same time; the clashing of their action causing "the evolution of heat." To use plain language, this idea seems no more conceivable than if it were said that the atoms (in the words of the Greek philosopher Empedocles designating these two tendencies) both *loved* and *hated* one another at the same time. If any two atoms were materially connected, such opposite actions might be intelligible, for, while gravitation would pull them towards one another, the material connection might hold, or push them apart. But, there being no material intermedium, how the two atoms can push-pull, or pull-push one another as above intimated, appears to be entirely beyond the power of the human mind to grasp.

65. *Cooling and Precipitation of the Primordial Vapor.*—But passing over this difficulty—"As fast as this

heat partially escapes by radiation, further approximation will take place, followed by further evolution of heat, and so on continuously. When a certain amount of heat and pressure is thus attained, some of the atoms will suddenly enter into chemical union." But another difficulty occurs here; for Prof. William Crookes and others maintain that gravitation can exist, or operate to approximate atoms, only after their chemical union has already taken place.* But, to continue—"When radiation has adequately lowered the temperature, these newly found primary atoms will precipitate . . . will aggregate into *flocculi*, as water precipitated from air forms clouds." These *flocculi*, acted upon by gravitation, "must not only be drawn to their common center of gravity, but also toward neighboring *flocculi*. Hence the whole assemblage of *flocculi* will break up into subordinate groups, each group concentrating toward its local center of gravity." In very large nebulæ, these groups would become stars and systems.

66. *Rotation by Precipitation of Irregular Flocculi.*—The flocculi have irregular shapes, somewhat like snowflakes, and, in consequence of this, their motion through the rarer substance of the nebula towards the center will not be in straight lines, but spiral or oblique. "What now must result when a *flocculus* having such oblique movement, encounters in its progress a medium that is always denser on the side towards the center than on the side away from it? There must perpetually be caused a deflection by the difference of pressure," which "will tend to bring the *flocculus* to one side or other of the common center of gravity." "Each *flocculus*, in describing its spiral course, must give

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*Nature, XXXIV, 432.

motion to the rarer medium through which it is moving." "The probabilities are infinity to one against all the motions thus impressed on the rarer medium balancing each other," and "the inevitable result must be a rotation of the whole mass of the rarer medium in one direction." The "preponderating momentum in one direction . . . must gradually arrest such *flocculi* as are moving in opposition, and impress its own motion upon them; and thus there will ultimately be found a rotating medium with suspended *flocculi* partaking of its motion."

Mr. Spencer's object here is chiefly to show how a rotation arises in a nebulous mass, such as the original solar spheroid. Now, let it be granted that gravitation will approximate the mass-atoms; that compound flocculi will consequently be formed; that the flocculi will be of irregular shape; that the central rarer medium will be most dense; and that the direction of motion of the flocculi towards the center will therefore be spiral or oblique—all of which are quite open to debate—it is still impossible that rotation of the mass as a whole can consequently arise.

If, at any distance from the mass-center, flocculi should be drawn towards that center, it is clear that the rarer medium through which the flocculi moved would also be attracted towards that center; and although the rarer medium may not have actually approached to the center so much as the flocculi, yet it would be held to that center firmly by the agency which carried the flocculi inwards. Therefore, from the utmost distance at which a flocculus would move inwards to the center, the rarer medium through which it moved would belong to the central mass towards which the flocculus was attracted. In fact, the rarer medium would be the so-called *atmosphere* of the central mass, and would always appertain and adhere to that mass at least until the formation of the first vapor-ring.

In that case, then, how can any motion of the mass as a whole ever arise? Does not the motions and the irregularities of the motions of the flocculi all arise in the mass itself? And would it not be as rational for us to hold that we could accelerate the Earth's rotation by sliding a large rock down the inclined east side of a mountain, or that we could increase the speed of a vessel by blowing upon its sails from a bellows placed in the stern, as to hold that any spontaneous, internal motions of the components of a mass will produce motion of that mass as a whole? Indeed, it is a well-known law of motion—the third law of Newton—that action and reaction are always exactly equal and opposite. Applying this law to special cases it means that a gun, *e. g.*, when fired, has precisely the same quantity of motion, or momentum, backward in the recoil as the bullet has forward, or that the rock which has rolled down the inclined side of a mountain conveys precisely the same amount of motion to the earth at the foot of the mountain, in one direction, as it has conveyed to the mountain itself in the opposite direction during its descent; or, which is a precisely analogous case, that the flocculus in its irregular descent towards the mass-center will transmit just as much and no more motion to the central mass in one direction as it has transmitted in its descent in the opposite direction to the rarer medium through which it fell. The supposed resistance offered by the rarer medium to a flocculus on the side next to the center can be nothing more than the mere displacement of the atoms or particles of that medium in one direction simultaneously with the deflection of the flocculus in the opposite direction. The flocculus may, for this illustration, be taken to be a solid body, like a marble or ball, which is falling through a vast number of smaller marbles or balls freely suspended in space. The large ball, as it starts upon its downward journey, will, it is supposed, strike against one of the small balls of the rarer medium, and so suffer deflection from its central course. But the small ball is also deflected; and, by the third law of motion, the momentum of each ball away from the radius would be precisely equal and opposite; and since every subsequent collision of the large ball with the small balls must be precisely similar in this respect to the first collision, as well as that all other flocculi must also be similar in the same respect to this particular flocculus—it clearly follows that however much denser may be the central medium, and however irregular may be the downward motion of the flocculus, there can never arise the slightest surplus of motion one way or the other that would tend to rotate the gaseous spheroid as a whole.

It may be, as Mr. Spencer states, that the probabilities are infinity to one against all the motions impressed upon the rarer medium by the falling flocculi balancing each other. It is equally improbable also that all the motions impressed upon the central mass thereby will balance each other. According to Mr. Spencer's theory, therefore, there would be, in all probability, a rotation of the rarer medium and a rotation of the central mass. But what is fatal to this theory is that the third law of motion teaches that the one rotation must be precisely equal in momentum and opposite in direction to the other. If by mutual friction the two rotations should counteract one another, there would be no preponderance whatever to rotation of the whole mass in any direction; and it would remain in a state of complete rest as respects axial rotation. And, on the other hand, the theory of the co-existence of the two rotations is emphatically denied by the uniform direction of the orbital motions of the planets and the axial rotation of the Sun. Mr. Spencer's theory seems, therefore, utterly untenable. It wholly fails to assign a possible cause for the rotation of the original solar spheroid. And without such rotation, the separation of vapor-rings is, of course, absolutely precluded by the law of gravitation.

67. *Rotation by Nebular Collisions.*—Now, if it be impossible that rotation of a vast nebulous mass can arise owing to internal agency, there is yet one, and only one, cause to which such rotation may be ascribed, namely, external agency. Certain scientists hold that rotation would very probably arise in this way. Let us examine, then, the premises involved, and see what rational conclusions may be drawn therefrom.

(*a*) *Density of the Primordial Vapor.*—The true ultimate postulate of cosmic evolution, as already intimated, is the one universal medium. This medium, in some way or other, is supposed to have eventually segregated into the nebulous masses of matter postulated by Laplace. Now, according to current views, no cause for such segregation is conceivable save the attraction of gravity drawing the surrounding matter towards local centers or nuclei; whence would result the nebular masses of which Laplace speaks. One of these nebular masses was originally our Solar System, and others became the fixed stars and nebulæ of the Sidereal System. Now the interval between the Solar

System and the nearest star or nebula is about twenty trillion ~~billions~~ of miles (the distance of Alpha Centauri), or about seven times the radius of the known Solar System. Assuming that the primordial vapor of the Solar System and of the contiguous systems have contracted at about the same rate, we have half the distance of our nearest sidereal neighbors, or about three-and-one- 3,500 ~~half~~ times the distance of Neptune, as the probable primitive limit of the homogeneous solar substance. To find the corresponding primordial density, we have, then, the total mass of all the principal bodies of the Solar System, about 324,878, and their total volume, about 1,285,833, the Earth being the unit of both mass and volume; consequently, the average density of the matter of our System to-day is 0.2526, the Earth's density being unity. But since the Earth's density is said to be 5.66 times that of water; and since the density of water is 773.28 times that of air, then the present average density of the matter of the Solar System with reference to air is about 1107.* Since volumes vary as the cubes of their like dimensions, and the radius of the present total volume, as above, of the Sun ~~Solar~~ System, being about 430,000 miles, and of the primordial Solar spheroid about 9,700,000,000 miles, then the present and primitive volumes of the Solar System will be to each other as $(43)^3$ and $(970,000)^3$, respectively. The original density is, therefore, $\frac{(43)^3 \times 1107}{(970,000)^3}$, or about 10^{-10}, that of air being unity, or *ten thousand times less than the density of the most perfect vacuum produced by a Sprengel air pump exhausting to one-millionth.*

(*b*) *Conditions of Nebular Condensation.*—This, according to present ideas, would be the probable density of the original universal medium. And by the attraction of gravitation (if in such a medium a center of attraction is rationally conceivable) this medium began to concentrate around local centers or nuclei. Slowly and gradually the interval between the borders of contiguous nebulæ widened. Having such extreme rarity, the periphery of a nebula would concentrate at equal rates upon all sides; and this would continue until the interval between neighboring nebulæ was very great. How, then, is it possible that motion of a nebula, as a whole, can arise? Condensation of a nebula towards its center can not surely cause a translation of that nebula in space; and neither can it cause the separation and translation in space of any portion of the nebula. Yet Prof. A. Winchell, in his book entitled "World-Life," page 170, states that "the most plausible conception of the forming process of nebulæ represents them as falling together and acquiring of necessity a rotary motion from an early stage of their existence"; and again he states that owing to these collisions "the chances of the causation of rotary motion are nearly as infinity to unity." And even Sir William Thomson maintains the probability of such collisions.*

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* Compare *Annuaire du Bureau des Longitudes*, 1881.

In another place (pp. 65–6), in a statement of an original theory of his own, Prof. A. Winchell says—"The universal world-stuff is scattered generally through boundless space. Perhaps, as Macvicar and Saigey have suggested, this primordial stuff in an extreme state of attenuation, is the ether, the medium whose vibrations, according to Dr. Young, striking the retina, produce the sensation of light. Out of this semi-spiritual substance germinates then the molecules of common matter. * * It may be, on the other hand, only a highly attenuated condition of ordinary matter, or matter in a state of ultimate dissociation. This characteristic world-stuff, born out of ether, in the depths of space, or however born, strewn through the depths of space, is acted upon by forces of attraction and probably of repulsion. The material particles, either as atoms, or less probably, as molecules, are drawn by mutual attraction into groups and swarms." This is essentially the same view of nebular evolution as that just described in the preceding pages, and in logical accordance with which it is wholly incomprehensible how "the collision of nebular masses" which Prof. Winchell so confidently postulates can arise. It is somewhat strange that Prof. Winchell does not attempt to explain the cause of these collisions, although he distinctly states that the difficulty of nebular rotation which he seeks to explain by them "has often balked belief in the nebular theory of the origin of the solar system" (p. 94). It certainly is no explanation of nebular rotations to say that they are caused by still more inexplicable collisions. Such attempts at explanation may be consistent with the idea of "the ever-present activity of an intelligent personability controlling and effectuating all the operations of nature" (p. 94); but it seems hardly consistent with the idea of natural causation.

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* *Nature*, XXXV, 299.

68. *Rotation by the Attraction of Distant Masses.*—Two other external causes of nebular rotation may be noticed, viz., the attraction of distant masses upon amorphous nebular forms and the attraction of distant masses upon precipitating nebular particles.

(*a*) With respect to the first, it may be said that such amorphous forms are themselves incompatible with the theory of gravitation. How vapor of such extreme tenuity, condensing on all sides upon an attracting center, could assume an irregular form can not be explained. Moreover we have no certain proof that such forms exist. The apparent irregular forms of nebulæ may be entirely owing to their immense distance from us, coupled with our own feebleness of vision.

(*b*) With respect to the other alleged cause of nebular rotation it may be said that the external masses which would influence a falling particle are so very distant from, and so nearly uniformly distributed around, the Solar System, that the preponderance of attraction, if any at all existed, must be so infinitesimal as to require almost an eternity to deviate the path of a particle a single hair's-breadth. Moreover, if we only enter into the details, we shall find that there really can not exist *any* preponderance of external attraction tending to rotation of a nebula. For, granting that an external attraction did exist, which measurably deflected the path of a falling particle towards the center from which this perturbing force emanated, it is manifest that the falling particles in the opposite hemisphere of the nebula would be acted upon with precisely the same energy and effect by this perturbing attraction. And the particles being equally deflected towards the same point, and moving in opposite directions, just what the deflection of the particles of one hemisphere tended to rotate the nebula in one direction, just so much precisely would the deflection of the particles of the opposite hemisphere tend to rotate it in the opposite direction, and both tendencies would exactly balance. And similarly also with any or all other external attractions, so that not even an infinitesimal preponderance of perturbing attraction could exist available for nebular rotation.

69. *Discordance of the Theory with the Facts.*—But nevertheless, nebular rotation is a fact—a fact which it is not at all attempted here to deny; for it is simply endeavored to be shown that the current theory does not furnish any rational explanation of it. Moreover, nebular rotation is not an ultimate or final fact like the mere existence of matter, or of force, any more than the rotation of the Earth is an ultimate fact. If the idea of rotation were applied to the material universe as a whole, the claim would then logically apply that this rotation was an ultimate, and therefore an inexplicable, fact. But it seems really absurd to claim that the rotation and translation of discrete masses of matter, such as the solar spheroid and the innumerable similar masses in the Sidereal System, are ultimate facts in the case of each body. Such a lavish applicaion of the idea of finality is simply an indication of a poverty of knowledge of the proximate facts of nature in the theory which unavoidably resorts to it, and the same remarks equally apply to nebular collisions; but, as already intimated, such collisions, in the early stages of nebular evolution, should be regarded as very improbable to say the least. It seems far more probable that the Solar System, stars, and nebulæ have each a proper orbital motion and their relative distances are always invariable beyond certain limits, much like the planets of our own system—a modification of the views of Kant, Hershel and Laplace. These two facts of nebular translation and nebular rotation must surely have had a natural cause; that is, they must have been brought about by the action of natural forces precisely in the same manner as other natural phenomena, with which we are familiar. And the action of these forces in producing such simple effects in such a multitude of

cases ought not to be beyond our comprehension in the case of nebulæ a whit more than in the case of more familiar phenomena, *if only the investigation takes place equally in each case upon a basis of facts.* But it appears from the cursory examination of the last few pages that nebular rotation and nebular translation are in all cases wholly inexplicable by the current theory of nebular evolution. And therefore it seems but logical to conclude that that theory does not furnish the basis of facts which alone will enable us truly to investigate these phenomena.

CHAPTER II.

THE ACCELERATION OF ABSOLUTE ROTATIONAL VELOCITY BY CONTRACTION.

70. *Modification of the Radial and Tangential Forces by Contraction.*—But let us assume the existence of nebular rotation. In defense of such assumptions it is sometimes claimed, as already intimated, that we always arrive sooner or later at questions of origin, which must for the time being remain unanswered. But the validity of this defense, except in the case of a proved ultimate fact, ought not to be allowed, as has just been shown. And neither should it be allowed with Prof. A. Winchell, *e. g.*, that "many different modes of action for the production of a particular result are possible;" but choose rather to hold that there can be but one correct explanation and one possible cause of any particular natural phenomenon, and that all other explanations of it are precluded by the true

one. It is not meant that a combination of effects, such as detetmine the Earth's orbit, may not have a combination of causes, some of which, from their smallness, may remain for a time undetermined. But the simple fact of the Earth's orbital motion (or the equally simple fact of nebular rotation) can obviously have but the one true general explanation.

But merely for the sake of examining the nebular hypothesis a few steps further, let us admit, with Helmholtz, that nebular rotation "must be assumed." Let us take the case of the original solar spheroid, and supposing either with Laplace, that it consists of a brilliant and dense nucleus, surrounded by a rare nebulosity or atmosphere, or with M. Faye, that it consists of a globular nebula gradually increasing in density from circumference to center; and granting its axial rotation, let us see if, according to current scientific views, the alleged vapor-rings could possibly be generated.

Evidently the centrifugal tendency at the equator of the spheriod, owing to its axial rotation, must have been less than the power of the central attraction prior to the genesis of the first ring. If this be granted, as, in fact, it must be and is by every supporter of the nebular hypothesis, then it can be shown that the more the spheroid contracts its volume, the less relatively to the central attraction will become the centrifugal tendency, thus making the projection of a vapor-ring an impossibility. Suppose, for illustration, that the initial velocity of the spheroid's equatorial surface was one mile per second; and suppose that subsequently the spheroid contracted to about one-third of its original diameter, or to the orbit of Neptune, then, by the law of gravitation, the central attraction at the smaller radius would be nine times as powerful as at the original radius; and, not only this, but at the smaller radius the surface is only one-ninth what it was at the larger radius; so that nine times the attraction upon the original surface is, after contraction, concentrated upon one-ninth of that original surface, and therefore the central attraction upon a unit of the contracted surface is eighty-one times as great as upon an equal unit of the original surface.[*] The centrifugal tendency would also become more powerful, but in a much smaller ratio; for the absolute velocity of the equatorial surface, as we shall shortly see, would still be no greater than one mile per second. And as the centrifugal force varies as the square of the velocity divided by the radius, it follows that, while the central attraction becomes eighty-one times as powerful owing to this shrinkage of the spheroid, the centrifugal or ring-making tendency becomes only three times as powerful. In other words, the central attraction increases as the fourth power of the radius diminishes, while the centrifugal tendency increases simply as the first power of the radius diminishes. And even if all that the current theory claims in this respect be granted, the centrifugal tendency would increase only as the *square* of the radius diminishes. Thus it is clearly seen that, whatever the radius of the spheroid would be, the central attraction is always in excess of the centrifugal tendency. And the greater the concentration of the spheroid, the less powerful relatively to the central attraction becomes the centrifugal, or ring-producing, force.

This appears to dispose of the theory of gravitation completely as accounting for the projection of rings from the original spheroid. According to that theory the central attraction increases as the square of the radius of the spheroid diminishes; and the centrifugal tendency increases exactly at the same rate as the central attraction. Then where is the force that causes the projection of the ring, since both the principal forces increase at the same rate? If there were no other consideration than this alone, the projection of rings would be quite inexplicable by the theory. But, as just seen, the central attraction increases, not as the square of the radius diminishes, but as the *fourth power* of the radius diminishes; and it appears also that the centrifugal force would increase only as the first power of the radius diminishes. We may now examine this last proposition more in detail, not indeed in connection with the projection of rings, for that is unnecessary, but in connection with the law of equal areas.

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[*] J. Homer Lane, *Am. Jour. Sci.*, July, 1870; A. Winchell, *World-Life*, p. 84; Newcomb's *Popular Astronomy*, p. 520.

If the initial equatorial velocity of the solar spheroid were *less* than three and one-half miles per second, and if, after shrinkage to Neptune's orbit, the equatorial velocity of the spheroid *was* three and one-half miles per second, then *something* must certainly have caused this acceleration of velocity. But what is there that would cause this acceleration? There are supposed to be but three forces which could act upon a rotating particle—a tangential force, a radial force of attraction, and a radial force of repulsion (heat). But since the last two act at right angles to the first, they can never transmit any portion of their influence either to increase or to diminish it. The radial factor of the circular motion would, of course, be increased by contraction of the spheroid, and this would obviously increase the absolute velocity of a rotating particle *while the contraction lasted*. But when the contraction was arrested by the radial repulsion, or by any cause whatever, there remains just the same tangential component as existed before contraction began. It is true, of course, that after contraction the fall per unit of time from the tangent towards the center of rotation is greater than before contraction. But this is the very circumstance which makes the centrifugal tendency increase as the radius diminishes, the increase of fall being wholly transformed into increase of centrifugal tendency. What is important here is that the tangential component remains wholly unchanged, *simply from the absence of any conceivable cause that would change it.*

Looking at the question by the principle of the conservation of energy, we arrive at precisely the same conclusion. A certain force (the radial, *i. e.*, the excess of the one over the other antagonistic radial force) is increased upon the particle; this increase of force upon it must produce an effect upon the particle, which effect is that it is carried farther inwards towards the center of the spheroid; and this effect continues just so long as its cause, the increase of the radial force, continues. The increase of the radial force expends itself in producing this effect precisely in the same way that the unincreased radial force expended itself in restraining the particle to a circular path; and it is just as illogical to look for additional effects, such as a modification of the tangential velocity in the one case any more than in the other.

71. *The Generation of a Repulsive Force, or Heat by Contraction.*—In the preceding article it has been assumed that a third force acted upon an equatorial particle of the spheroid—a force of repulsion urging the particle from the center. The difficulty of conceiving how this force of repulsion for the particle can emanate from sister particles from which in the same moment emanate a force of attraction for the particle, has been already referred to.

But let us look at this assumption of a repulsive force, or heat generated by contraction, more closely. Prof. Simon Newcomb, speaking of the Sun's heat says: "As his globe cools off it must contract, and the heat generated by this contraction will suffice to make up almost the entire loss."* Speaking of a gaseous body, he again says: "The more heat such a body loses the hotter it will become. By losing heat a gaseous body contracts, and the heat generated by the contraction exceeds that which it had to lose in order to produce the contraction." In other words, cooling causes contraction and contraction causes heat; or, briefly, *cooling* causes *heat*. In fact a *little cooling* causes a *great deal of heat*. In a gaseous body, according to Prof. Newcomb, the loss of heat to cause contraction is less than the gain of heat which that contraction generates; from which it would seem that the more a body cooled, the hotter it would get; and from which, if any conclusion whatever is allowable from such apparently absurd premises, it would follow that such a body could never cool, and therefore never contract, at all. Yet in view of all the insurmountable difficulties here pointed out, Sir W. Thomson, President of the Royal Society of Edinburgh, Scotland, communicates a paper, March 7, 1887, to that Society, stating that in the light of thermo-dynamical principles. Laplace's theory is seen to be, not a mere plausible theory, but *a statement of actul fact*. He has not indeed committed himself to the above view of Prof. Newcomb, for in a lecture upon the Sun's heat † he assumes that his hearers are no longer misled by such a delusion. Still he maintains that the heat generated by the Sun's contraction owing to cooling differs so little from as to

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***Pop. Astron.*, 5th ed., pp. 519-20.

† At the Royal Institution, London, Jan. 21, 1887.

be practically equivalent to, the heat that is radiated from the Sun in the same time.* But this view appears to be only a little more logical, or rather a little less illogical, than the other. For if the gain and the loss of heat at the Sun's surface is practically equivalent, how comes it that the Sun cools at all so as to admit of contraction?

Now if it be held that the gain of heat generated by contraction does not exceed the loss of heat necessary to cause that contraction (which is the view of Thomson, Siemens, Lockyer, Helmholtz, Williams, etc.), then it obviously follows that the force of repulsion (or the heat) *after* contraction is no greater than it was *before* contraction; which for the present purpose wholly eliminates this agent as a factor in the generation of planet-rings upon the bosom of the solar spheroid. And therefore the tendency to the projection of such rings from the contracted surface of that spheroid as compared with the tendency to non-projection of such rings, or adherence of all matter to the spheroid itself, remains as determined by the centrifugal force of rotation and the central force of attraction; that is, as the first power of the contracted radius is to its fourth power, in favor of the latter, supposing that the tendency to projection and to non-projection were equal, or balanced, at the original surface.

72. *Conflicting Theories of Ring-Projection.*—In further illustration of the chaotic confusion to which the nebular hypothesis, as subject to the law of gravitation, leads, it may be remarked that Sir David Brewster approved a calculation by M. Babinet that when the solar spheroid had contracted to the present orbit

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**Macmillan's Magazine*, March 1862, and Thomson and Taits' *Natural Philosophy*, Vol. I, Part II, Appendix E.

of the Earth, its period of rotation, according to the nebular hypothesis (assuming the accepted solar density and equal angular velocity of all parts) must have been 3,181 years! although the Earth itself, which by the same hypothsis was but a portion of the solar surface at that time, performs its revolution in one year! Mr. Herbert Spencer disapproves of such calculations, and speaks of "the extreme difficulty, if not impossibility, of subjecting the nebular hypothesis to mathematical treatment."[*]

M. Faye, disbelieving the possibility of ring-projection according to the conceptions of Laplace, says.[†]

"By the intervention of heat and the play of centrifugal force, Laplace caused to be produced a totally different distribution of the mass and of its movements. This corresponds, to a certain extent, with what we see. But *this intervention of heat is itself pure hypothesis.* To justify it we must suppose, with Poisson, that there are in the universe regions with very different temperatures, and that the primitive globe, by virtue of its motion of translation, had passed into one of the hottest." But he assigns no cause whatever for such ring-projection according to the somewhat different conceptions from that of Laplace which he himself entertains of the solar spheroid. He gets over the difficulty thus: "If, then, trains of matter somewhat circular, in a word, rings like those of Saturn, . . . become finally established in the bosom of the nebula" —without attempting to show the slightest physical cause of their becoming so established.

Another view of Philipp Spiller is that the planets are projected out from a liquid Sun by the centrifugal force of rotation and a *tidal swell* caused by another body; that Saturn was projected by the tidal swell caused by Uranus; that Uranus was projected by the tidal swell caused by Neptune.[*] But the projection of Neptune itself is not accounted for; and it is moreover disputed by modern astronomers that *even now* the Sun has attained a liquid condition. And Mr. R. A. Proctor expresses his belief upon the subject as follows: "No one who applies the laws of physics, *as at present known*, to the theory of the simple contraction of a great nebulous mass formerly extending far beyond the orbit of Neptune, till, when planet after planet had been thrown off, the sun was left in his present form and condition in the center, will fail to perceive enormous difficulties in the hypothesis. * * * Has it ever occurred, I often wonder, to those who glibly quote the nebular theory as originally propounded, to inquire how far some of the processes suggested by Laplace are in accordance with the now known laws of physics?"[†] And what is Mr. Proctor's improvement upon the Laplacean conception? Simply the addition of *accretion* to contraction, and an assumption of a central nucleus and subordinate nuclei with *independent motions!*—an assumption which, although apparently countenanced by men of such eminence as Kant, Sir W. Herschel, and Herbert Spencer, is so manifestly improbable that it need not here be discussed.

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[*] *First Principles*, p. 365.

[†] *Comptes Rendus*, March 22, 1880.

The theory of Laplace is the one now generally accepted. M. Wolf, in his recent work on "Cosmogonic Hypotheses," shows that as completed by the labors of M. Roche and other *savants*, that theory still answers best to the conditions required of a Cosmogonic Hypothesis. Even the present writer has no objection to it in the main; these criticisms, as already intimated, being directed almost entirely to the application thereto of the theory of gravitation.

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[*] Prof. G. H. Darwin holds a nearly similar view concerning the retirement of the lunar mass from the semi-fluid Earth.

[†] *Humboldt Library of Science*, Vol. III, p. 351.

73. *The Law of Equal Areas.*—Referring once more to the alleged increase of absolute tangential velocity by contraction, which appears to be the main cause of ring-projection according to modern physicists, what cause, it may be asked, do these physicists assign for the increase of absolute tangential velocity? Our search for the assignment of this cause will be rewarded in nearly all cases by such expressions as these: "If the principle of the conservation of areas is not fallacious," etc.; "Since the angular velocity varies inversely as the square of the radius," etc.; "By a mathematical principle of physics known as the law of equal areas in equal times," etc. These are the explanations of the phenomenon chiefly to be met with; the law of equal areas in equal times being evidently regarded as a demonstrated fact. But the so-called great second law of Kepler, involving the variation of the absolute tangential velocity of every revolving body with the variation of its radius of revolution, obviously could not be adopted without some attempt at explanation. Indeed, such an attempt has been made and fortunately by the best of authorities, Sir Isaac Newton; to whom nearly all other authorities refer the inquirer.

Sir John Herschel, having occasion to speak upon the subject,* says: "As an abstract dynamical proposition, the reader will find it demonstrated by Newton, in the first proposition of the *Principia*, with an elementary simplicity to which we really could add nothing but obscurity by amplification, that any body, urged toward a certain central point by a force continually directed thereto, and thereby deflected into a curvilinear path, will describe about that center equal areas in equal times." "It is a property of orbital rotation under the influence of central forces *generally*," he observes, "and, as such, we daily see it exemplified in a thousand familiar instances. A simple experimental illustration of it is to tie a bullet to a thin string and, having whirled it round with a moderate velocity in a vertical plane, to * * allow it to coil itself round a cylindrical rod held very firmly in a horizontal position. The bullet will then approach the center of motion in a spiral line; and the increase of its angular velocity, and the rapid diminution of its periodic time when near the center, will express, more clearly than any words, the compensation by which its uniform description of areas is maintained under a constantly diminishing distance."

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*Outlines of Astronomy, p. 324.

By some unaccountable oversight, the eminent Herschel here errs. The increase of the bullet's angular velocity, and the rapid diminution of its periodic time, does not necessarily express the compensation by which its uniform description of areas is maintained under a constantly diminishing distance. The expression of such compensation involves *more* than an increase of angular velocity and a diminution of periodic time. It involves, in fact an increase of the bullet's absolute velocity; and not only an increase of its absolute velocity, but of the *tangential component* of its absolut velocity. For a uniform tangential velocity of the bullet involves, under diminishing distance, both an increase of angular velocity and a diminution of periodic time, as well as an increase of absolute velocity;

but it does not involve a uniform description of areas in equal times. This is very simply demonstrated. The string or distance, at the beginning of any unit of time is the base of the triangular area described in that unit of time, and the tangential velocity in that unit of time determines the perpendicular height of that triangular area. Now, as the distance, or the base of the triangle, is less in any unit of time than in the preceding unit, it is very plain that the areas described in successive units can not be uniform with a uniform perpendicular height, or tangential velocity. The familiar illustration which Herschel gives of the law of equal areas in equal times turns out, therefore, to be no illustration of that law at all. An essential element is lacking—the increase of tangential velocity; and that element the illustration does not involve, nor is it even mentioned by the illustrious author. We turn then to Newton's Principia, where Herschel assures us that we shall find a simple demonstration of the law in the first proposition of that much-neglected volume, and this is what we find:—

"PROPOSITION I.

The areas which revolving bodies describe by radii drawn to an immovable center of force do lie in the same immovable planes, and are proportional to the times in which they are described.

"For, suppose the time to be divided into equal parts, and in the first part of that time let the body by its innate force describe the right line AB. In the second part of that time the same would (by Law I.),* if not hindered, proceed directly to c, along the line

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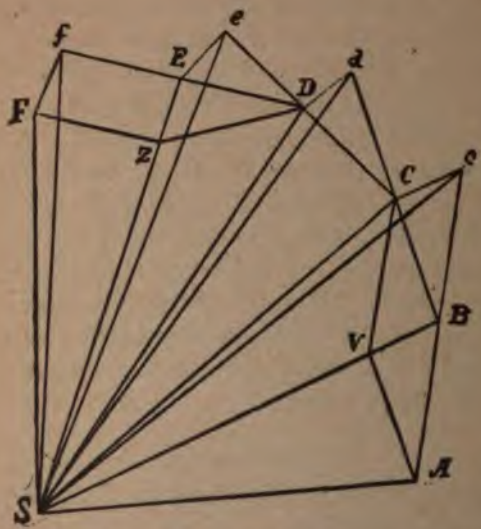
*LAW I. Every body perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon.

Bc, equal to AB; so that by the radii AS, BS, cS, drawn to the center, the equal areas ASB, BSc, would be described. But when the body is arrived at B, suppose that the centripetal force acts at once with a great impulse, and, turning aside the body from the right line Bc, compels it afterwards to continue its motion along the right line BC. Draw cC parallel to BS, meeting BC in C; and at the end of the second part of the time, the body (by Cor. I. of the Laws*) will be found in C, in the same plane with the triangle ASB. Join SC, and, because SB and Cc are parallel, the triangle SBC will be equal to the triangle SBc, and therefore, also to the triangle SAB. By the like argument, if the centripetal force acts successively in C, D, E, etc., and



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* Cor. I. *of the Laws.* A body by two forces conjoined will describe the diagonal of a parallelogram, in the same time that it would describe the sides, by these forces apart.

makes the body, in each single particle of time, to describe the right lines CD, DE, EF, etc., they will all lie in the same plane; and the triangle SCD will be equal to the triangle SBC, and SDE to SCD, and SEF to SDE. And therefore, in equal times, equal areas are described in one immovable plane; and, by composition, any sums SADS, SAFS, of these areas, are one to the other as the times in which they are described. Now let the number of these triangles be augmented, and their breadth diminished *ad infinitum;* and (by Cor. 4, Lem. III)* their ultimate perimeter ADF will be a curve line; and therefore the centripetal force by which the body is perpetually drawn back from the tangent of this curve, will act continually; and any described areas SADS, SAFS, which are always proportional to the times of description, will, in this case also be proportional to these times. Q. E. D.

"Cor. I. The velocity of a body attracted toward an immovable center in spaces void of resistance, is reciprocally as the perpendicular let fall from that center on the line that touches the orbit. For the velocities in these places A, B, C, D, E, are as the bases AB, BC, CD, DE, EF, of equal triangles, and these bases are reciprocally as the perpendiculars let fall upon them."

It will be seen that, from the law of equal areas, the corollary (Cor. I) necessarily follows that the tangential velocity of a revolving body *increases* as its distance from the center *diminishes.* This is the essential point of which we have all along been trying to find some explanation in harmony with the present theory, and the point of which Herschel fails to take any cognizance in the "familiar illustration" above noticed. But does Newton really explain this point? His argument is indeed clear and simple and admirable verbally; but when we examine it closely, it seems to involve most difficult and even inconceivable propositions. The first of these which we will notice—apparently an innocent one, and not employed by Newton alone, but by nearly all mathematicians, and in a number of different ways—is that *the perimeter of a polygon can be transformed into the perimeter of a circle, when the number of its sides is increased ad infinitum.* Newton says—"Let the number of these triangles" (forming the polygon) "be augmented and their breadth diminished *ad infinitum;* and . . . their ultimate perimeter will be a curve line." This is true if by infinite subdivision a magnitude can be annihilated, for that is, in plain words, what it means. Otherwise it can not be true. A curve is a line no part of which, however small, is a straight line. If the straight lines which form the bases of the triangles of a polygon become by infinite division a curve, then the ultimate base of each division of such triangles must have become something less than a straight line—must have become a mere point, which has no magnitude. Thus the original sides of the polygon have each become changed into an infinite number of points having no magnitude—have, in fact, become annihilated, for, reversing the process and multiplying the ultimate point, or no magnitude, by infinity, we still have no magnitude. Nothing taken an infinite number of times is still nothing—which ought to teach us that each part of a magnitude, even though infinitely divided, is still a magnitude, and that each ultimate part of a straight line, however subjected to division, is still a straight line, and so can not be a component of a mathematically accurate curve line.

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* LEMMA III. The same ultimate ratios are also ratios of equality when the breadths AB, BC, CD, etc., of the parallelograms are unequal and are all diminished *ad infinitum.* COR. 4, and therefore these ultimate figures (as to their perimeters) are not rectilinear, but curvilinear limits of rectilinear figures.

The eminent Prof. William Kingdon Clifford, in an admirable discourse at the Royal Institution, London, justly criticises some "absolute," "infinite," and "unbounded" philosophical conceptions arising from the assumption of theoretical exactness in the laws of geometry, which seems to fit this case exactly. He says that in these cases there is always something which we do not know, and that such false conceptions are attempts "to found a positive statement upon this ignorance, which can hardly be regarded as justifiable." He truly observes that a reasonable conception is one which is framed "in terms of ideas justified by previous experience without itself contradicting that experience," and that "a wise man only remembers his ignorance in order to destroy it," instead of framing it into a so-called mathematical demonstration. "Mathematics," warns Professor Huxley, "is like a mill, and what you take out of it depends entirely on what you put in."

The second apparently inconceivable proposition or assumption which Newton makes naturally follows from the first. It is of much greater consequence here, however, as upon it rests the entire weight of the argument. This assumption is that *the centrifugal force, or the tangential velocity of a body revolving about a center, can cause that body to move in any unit of time, in the path produced of the preceding unit of time.* Newton does not make this assumption directly; in fact he bases such impulsion of the body upon his first law of motion. But the assumption certainly seems not the less clearly involved in his argument. "For suppose the time to be divided into equal parts," he says, "and in the first part of that time let the body, by its innate force, describe the right line AB. In the second part of that time the same would (by Law I.), if not hindered, proceed directly to c along the line Bc, equal to AB, so that by the radii AS, BS, cS, drawn to the center, the equal areas ASB, BSC, would be described." Here, then, lies the error. "In the second part of the time the body would proceed *directly to c, along the line Bc.*" Similarly in the third part of the time, the body would proceed *directly to d, along the line Cd;* in the fourth part, *directly to e, along the line De;* in the fifth part, *directly to f, along the line Ef;* and so on. The assumption is clearly implied here that each of the lines ABc, BCd, CDc, DEf, are right lines. Indeed if they were not right lines, the geometrical theorem which Newton employs, and on which the whole argument depends (viz., that triangles on equal bases *and between the same parallels* are equal), could not apply. Now it is certain that this argument is employed with respect to motion in a curve, for eventually these same right lines are by a process of infinite division alleged to be reduced to a curve line. But is it possible that the tangential force of the body can impel it in the direction of the sine, or chord, produced, of any portion of that curve? The ultimate curve line would certainly pass through the points A, B, C, D, E, F, etc. The lines AB, BC, CD, DE, EF, etc., would therefore be chords of the curve line; and the lines Bc, Cd, De, Ef, in which Newton assumes the centrifugal force would impel the body, would be continuations of these chords. But it is evidently absurd to suppose that the tangential force could impel the body in the continuation of a chord of its curved path, for, if the force which holds the revolving body to the center should be destroyed, the body, in obedience to the tangential force, would move in a right line *tangent to its previous curved* path; and it is obviously impossible for a tangent and a chord to the same point of a curve to be the same, or to be parallel, or to be in the same direction.

Newton's assumption that the tangential force would impel the body, not in a tangent to its curved path, but in a continuation of a chord of that path, is, therefore, erroneous. The line Bc must be supposed to unite angularly with the line AB at the point B. The triangles ASB and BSc are not, therefore, between the same parallels, and, being on equal bases, they can not be equal. Consequently Newton's demonstration utterly fails to demonstrate, and in the absence of any assignable physical cause for the essential acceleration of absolute tangential velocity which the law of equal areas involves (see article 70), it certainly appears that that essential acceleration, and consequently that law, remains without any foundation in fact.

74. *Discordance of the Theory with the Facts.*—From all points of view, then, the nebular hypothesis, as subject to the theory of gravitation, seems rationally unapproachable. If we ask how the nebular primordial rotation originated, we find that every assignable cause eludes rational conception. Whether it be the centerward spiral movement of irregular flocculi through a rarer atmosphere, the collisions of nebular masses, or the various attractions of distant nebular masses either upon the concentrating particles of a nebula, or upon amorphous nebular forms—each such assignable agency, when ultimately analyzed, proves to be entirely visionary. Yet it is undeniable that such rotation must actually have existed. And, for the moment, granting the existence of primordial rotation as an ultimate fact, when we inquire how this rotation became accelerated

so as to project the planets outwards from the solar spheroid, we are met by equally insurmountable difficulties. For, if we assume the agency to be contraction of the spheroid, we find that such contraction increases the central attraction much more rapidly than it does the tangential, or ring-producing force; if we assume the generation of a repulsive force, or heat, by such contraction, it leads us to the self-contradictory conclusion that the cooling of the solar spheroid engendered a more intense degree of heat than that which existed before the cooling began; and when we examine the alleged principle in accordance with which the tangential force is said to be sufficiently augmented by contraction of the spheroid to project the planet-rings, we find that principle to be wholly unfounded in reason. While we know that nebular rotation, translation and acceleration of the tangential velocity of rotation, must have taken place and must have physical causes, it seems that all our inquiries after such causes are utterly baffled by some ever-present preconception which enters the fabric of our thoughts, or upon which our inquiries are based; and this ever-present premise is evidently none other than the theory of universal gravitation.

It is not contended that the theory of gravitation, which by implication underlies the nebular hypothesis, is conclusively proved by the foregoing criticisms to be erroneous. It is contended only that as the general assumptions of the nebular hypothesis are undeniable, and yet remain rationally inexplicable, we have in this an excellent reason for suspecting the truth of that underlying theory. Every theory *should* explain *all* of the facts it professes to account for. That the main facts are inexplicable by it, although strongly tending to condemn it, is still not sufficient ground, perhaps, for finally rejecting it. What may fully justify such rejection is indisputable evidence that some of the main facts are positively inconsistent with, and contrary to, the theory. This evidence it is the purpose now to adduce from the most familiar and important phenomena of the Solar System.

CHAPTER III.

THE PROBLEM OF THREE BODIES.

75. *Data of the Problem.*—Let it be assumed that the theory of gravitation fully accounts for all that it claims in the domains of the nebular hypothesis—the rotation of the solar spheroid, the projection of planet-rings, the orbital motions of the resulting planets, the uniformity of directions and planes of orbital motions, and the genesis from the planets of satellites manifesting similar characteristics. And let us apply the force of gravitation, in accordance with the law of inverse squares, to a single instance in the system thus generated. The most familiar instance is that of the Earth, the Sun, and the Moon. Let us consider the celebrated problem of three bodies, once more using these for a special case. For brevity we will designate the Earth, the Sun, and the Moon by their initial letters E, S, and M, respectively; and we will suppose E to be at its mean distance, or about 93,000,000 miles, from S, and M to be at a point between full and new Moon 54° 44′ distant from the latter and at its mean distance, or about 240,000 miles from E; with the apogee of the lunar orbit at, or nearly at, new Moon. The object of taking M at

the given point of its orbit around E is that, at this point, the orbital forces upon M are supposed to be balanced, so that the latter has no tendency either to recede from, or approach towards, its primary. According to Sir John Herschel the distance of the given point from new Moon is 64° 14′,* but Prof. R. A. Proctor maintains that the balancement takes place at the point first given;† and this point is selected here chiefly because it is the less favorable to the purpose here to be served. At the given point, M would be some 140,000 miles nearer to S than E is, and, taking the Moon's apogeeal distance from the Earth at about 259,000 miles,‡ M will yet approach S about 119,000 miles before it reaches syzygy, or the point at which it is called new Moon. And as the synodic period of M is about 29½ days, the time required to traverse the arc of 54° 44′ will be about 4½ days, and therefore the average approach per second of M towards S between the given point and the apogeeal point at syzygy will be $\frac{119{,}000}{4\frac{1}{2}\times 24\times 60\times 60}$, or about $\frac{3}{16}$ mile.

76. *Perturbation of the Moon's Motion Owing to the Sun's Distance-Variation.*—Now at the given point we may readily find, according to the law of gravitation, that the force of the attraction of S upon M will be of such value as to cause the latter to fall towards S a distance of about 0.01 ft. in one second. But since at the given point the orbital forces upon M are supposed to be balanced, we may assume that this attraction of S upon M is wholly antagonized by the centrifugal force of the latter in its solar orbit. At the end of the first second after leaving the given point, however, M will have approached S a distance of $\frac{3}{16}$ mile; and consequently,

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**Outlines of Astronomy*, art. 676. †*The Moon*, p. 81, Note.

‡Newcomb's *Popular Astronomy*, p. 312.

by the law of gravitation, the attraction of S upon M will be greater than 0.01 ft. in one second by a quantity x as indicated in the following proportion:

$$(92{,}860{,}000-\tfrac{3}{10})^2 : (92{,}860{,}000)^2 = 0.01 : 0.01+x;$$

from which the value of x is found (very approximately by multiplying $\frac{3}{10}$ by 0.01 and dividing twice the product by 92,860,000) to be about 6×10^{-11}. At the end of the second second, the approach of M towards S would be twice as great, or $\frac{6}{10}$ mile, and consequently x, or the increase of the attraction of S, would be twice as great, or 12×10^{-11}. At the end of the third second, the approach is $\frac{9}{10}$ mile, and the increase of attraction upon M is 18×10^{-11}. And so on. The increase of attraction in the first second, if not counteracted, would obviously urge M at the same rate in all subsequent seconds; and similarly with the increment of attraction in the second, third, etc., second; so that the rate of fall of M towards S in any second owing to these momentary increments of solar attraction upon M would be equal to the sum of all the falls in that and the preceding seconds up to the starting point.

Thus, in the	1st	second,	the fall	is	6×10^{-11} ft.
In the	2d	"	"	"	$(12+6)\times10^{-11}$ ft. $=18\times10^{-11}$ ft.
"	3d	"	"	"	$(18+18)\times10^{-11}$ ft. $=36\times10^{-11}$ ft.
"	4th	"	"	"	$(24+36)\times10^{-11}$ ft. $=60\times10^{-11}$ ft.
"	5th	"	"	"	$(30+60)\times10^{-11}$ ft. $=90\times10^{-11}$ ft.
. . .	. . .	. . .	. . .	. . .	. . .
"	388800th	"	"	"	4½ ft.

Now since the orbital forces are balanced upon M at the given starting point, so that it has no tendency either to recede from, or approach towards, E, the foregoing series of momentary increments of solar attraction obviously constitute a perturbing force pulling M away from E and towards S; and we see that, if left to itself, the effect of this perturbing force for the

4½ days, or 388,800 seconds, during which M moves from the given point to the apogeeal point at new Moon, is such as to generate a velocity of M directly towards S of not less than 4½ ft. per second at the latter point; which is more than a thousand times greater at that point than the effect of E's restraining attraction in the same time. Therefore, unless some other equal and opposite perturbing force, or forces, are generated at the same time, it is very obvious that, in accordance with the theory of gravitation, M would be carried rapidly inwards to S, instead of actually moving away from S to the opposite side of E. Let us inquire, then, what other perturbing forces upon M can possibly arise between the two points in accordance with the present theory.

Starting from a point where the orbital forces are in equilibrium, as in the instance given, there are only two classes of perturbing forces that can possibly arise as the revolving body leaves that point, namely, those arising from variations of distances from attracting centers and those arising from variations of orbital velocity around these centers. Now there are only two attracting centers concerned in this problem, or E and S; and these two give rise therefore to four perturbing forces upon M, and no more. These perturbing forces are (1) that due to distance-variation of M from S, (2) that due to distance-variation of M from E, (3) that due to velocity-variation of M around S, and (4) that due to velocity-variation of M around E. The first of these has just been determined; we may now proceed to discuss the others.

77. *Perturbation of the Moon's Motion Owing to the Earth's Distance-Variation.*—It has already been stated that at the first given point of M's orbit, that

body is at its mean distance, or 240,000 miles, from E, at which the value of E's attraction is about 0.0044 feet per second; and that at the second given point, or the apogee of M's orbit at new Moon, the distance of M from E is 259,000 miles. Between the two points therefore M has receded from E a distance of 19,000 miles, or nearly $\frac{1}{20}$ mile per second; and it follows that, in every second after leaving the given point, E's attraction upon M would become less and less owing to this increase of the distance at which it acts. To find this diminution of E's attraction in the first second, we have the following proportion, nearly similar to that of the preceding article:

$$(240,000-.049)^2 : (240,000)^2 = 0.0044 : 0.0044+x;$$

where x is found to be 17×10^{-10} ft. In the second second the recession, being twice as great, x would be twice as great, or 34×10^{-10} ft. In the third second the recession would be three times as great, and would therefore be 51×10^{-10} ft. And so on. These diminutions of E's attraction upon M would obviously cause corresponding excesses of M's centrifugal force around E, which consequently would urge M away from E and towards S. In the first second, the excess would urge M away from E a distance of 17×10^{-10} ft., at which rate it would of course keep moving in each subsequent second, if not prevented by some other cause. In the second second M would be urged a distance of 34×10^{-10} ft., which, like the first, and every succeeding impulse, would also continue through subsequent seconds. So that the total fall in any second, owing to this series of impulsions, would be the sum of the fall in that second and those in all the preceding seconds. The falls in successive seconds would thus have a common difference of the second order of 17×10^{-10} ft.; according to which the fall in the last second owing to this series is about $\frac{(388800)^2\times17\times10^{-10}}{2}$, or 128 ft.

78. *Perturbation of the Moon's Motion Owing to Variation of its Velocity Around the Sun.*—The two series of perturbing forces owing to distance-variation being thus found to act in unison, we turn to the perturbing forces which may be due to variations of velocity. We may first consider those due to such variation around S. As M leaves the first given point, it moves inwards to S, and also its motion around E is opposite to its motion around S, and the latter is therefore diminished by a very considerable portion of the former. The mean velocity of M around S is about 19 miles per second. If the velocity is variable and the distance constant, the centrifugal force varies directly as the square of the velocity. If both the distance and velocity are variable, the centrifugal force varies directly as the square of the velocity and inversely as the distance. As M approaches S, therefore, it is necessary that its velocity around that body should be diminished in order to preserve its centrifugal force constant. We have now to determine whether the diminution of velocity due to the opposition of the two orbital motions of M is sufficient, or more than sufficient, for this purpose. At the given starting point, M is some 190,000 miles in advance of E in its solar orbit, and 4½ days, or 388,800 seconds, afterwards, M is exactly between E and S. This would involve a diminution of M's velocity around S of nearly ½ mile per second. But M's velocity has been diminishing ever since last quarter. This last point is in advance of the given point with respect to M's solar orbit, about 50,000 miles; and it required about 250,000 seconds for

M to move from last quarter to that point; which involves a diminution of velocity of about $\frac{1}{5}$ mile per second before the given point was reached. This reduction of velocity preceding the arrival at the given point, was presumably one of the circumstances required for the equilibrium of the orbital forces at that point; and it is necessary therefore to deduct it from the rate of reduction after the given point was passed in order to compare M's velocity at this point with its subsequent velocity. Deducting $\frac{1}{5}$ mile from 0.49 mile leaves 0.29 mile, which is the comparative rate of diminution after leaving the given point. Now since M's actual velocity at that point is some 19 miles per second, then to find the diminution of M's centrifugal force around S corresponding to this diminution of velocity, we have the following proportion:

$$\frac{(19)^2}{92{,}860{,}000} : \frac{(19-0.29)^2}{92{,}860{,}000-0.3} = 0.01 : 0.01-x;$$

whence x is found to be 0.0003 ft. And since the diminution of velocity in each second after leaving the given point is about the same, and that of the distance from S at all times comparatively inconsiderable, the diminution of the centrifugal force around S in each subsequent second will also be about the same. Now the diminution of M's centrifugal force around S obviously leaves an equivalent portion of the attraction of S in excess upon M in each second, which, like the other perturbing forces, would of course draw M away from E and towards S. In each second the pull in this direction is 0.0003 ft., which, as in the other series is effective also in all subsequent seconds. And therefore the rate of fall in the last second is 0.0003 ft. × 388,800, or 116 ft.

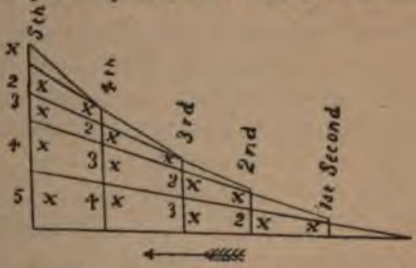
79. *Perturbation of the Moon's Motion Owing to Variation of its Velocity Around the Earth.*—There

now remains to consider only the variation of M's velocity around E. Since all the perturbing forces already determined tend to draw M towards S, that is somewhat indirectly in the direction of M's orbital motion around E in the period considered, it is obvious that the velocity of that motion would gradually increase for this reason after M leaves the given point. This would evidently increase M's centrifugal force around E and the increase of this force would constitute a perturbing force which, between the given points, would also urge M towards S and therefore in unison with the other perturbing forces.

(*a*) *Back-action of the Earth's Attraction.*—But there is one circumstance which, it is alleged, would diminish M's velocity around E between the given points. At the starting point, the distance between the two bodies was stated to be about 240,000 miles, while at new Moon, where the apogee of M's orbit is assumed to be situated, the distance between the two bodies is 259,000 miles. Between the two points, therefore, M recedes from E a distance of 19,000 miles. In consequence of this the orbital motion of the former is somewhat oblique to the direction of E's attraction, instead of at right angles to it, so that a portion of E's attraction is thus brought to act in opposition to M's motion, and the latter is consequently diminished. As this point is of considerable theoretical importance in this inquiry, it may be well to examine it in some detail.

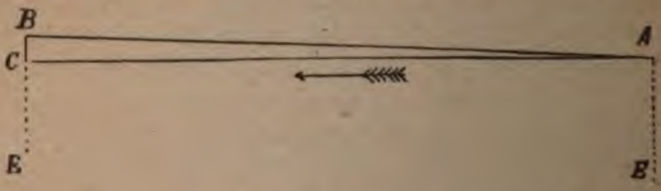
We may study this back-action of E's attraction under the following sub-heads: The actual recession of M from E in each second; the effect of this recession upon M's velocity in each second; and the effect of the change of velocity upon M's centrifugal force around E in each second.

I. Let x denote the recession of M from E at the end of the first second after leaving the given point. We may assume for the sake of simplicity that this *direct* recession is uniform in each second between the given points; and this *direct* recession in each second we may designate as the *primary* recession to distinguish it from the *indirect* recession now to be explained. Then at the end of the second second there would be the primary recession x and the indirect recession $2x$ owing to the deflection of M's path in the first second. In the third second there would be the primary recession x, the secondary recession $2x$ owing to the primary recession in the second second, and the secondary recession $3x$ owing to the primary recession in the first second. And so on, as indicated in the diagram (in which however the relative values of the recessions are vastly exaggerated); the arrow indicating the direction of M's motion around E.



The total recession at the end of the 388,800th second, or at new Moon, is therefore the sum of the series $x, 2x, 3x, 4x, \ldots. 388{,}800x$, or $75{,}582{,}720{,}000x$, which must be equal to the actual recession, or 19,000 miles; whence x equals about 0.0013 ft. The recession *during* any particular second is of course the difference between the total recession in that second and that in the second immediately preceding it. During the first second, then, the recession is x, during the second second $2x$, during the third second $3x$, during the fourth second $4x$, and so on.

II. Evidently the inclination of M's path in any moment to the direction of E's attraction is determined by the recession which takes place *during* that second: for if there were no recession at all during any particular second, M would be precisely the same distance from E at the end of the second as at its beginning; so that its path for that moment would be at right angles to E's attraction. And the greater the recession during any moment the greater the inclination of M's path for that moment to E's attraction. Now the recession during the first second is 0.0013 ft., as just found; and the length of M's path around E in the same time is several million times greater, or 3,373 ft. Let M's momentary path around E be represented by AB, and the momentary recession or x, by BC; AC being at right angles to AE, or BCE, the direction of

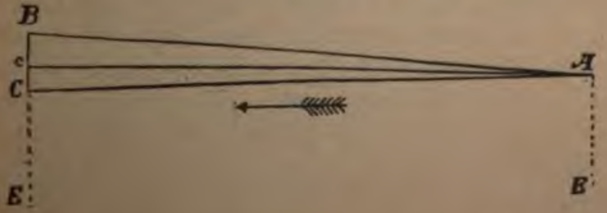


E's attraction. The question then becomes, how much *shorter* AB is than AC, the path which M would traverse but for the recession BC. Here we at once see the absurdity of supposing that the oblique path (*i. e.* the hypotenuse of the triangle ABC) can be shorter than the rectangular path (the base of the triangle): which absurdity plain common sense also points out when we only reflect that a powerful perturbing force *does actually pull* M outward from E, thus asserting its superiority over every obstacle in its way, and thus, *of necessity*, *elongating* M's momentary path instead of shortening it. However, if the shortening of M's oblique path owing to the recession be by any means possible, or conceivable, it certainly could not exceed in amount the difference between the two larger sides of the triangle of which the value of E's attraction in one second is the other side. This in any case would be its maximum value. The only way in which we can imagine that this shortening would take place, is by assuming the reverse of the fact, or that the action of E's attraction alone would cause M to describe the path AB instead of the path AC, and that the effect of the recession would be to cause M to describe the path AC instead of the path AB. On this violent assumption, M's momentary path or velocity would be diminished by E's attraction; and the diminution would obviously be the difference between the two paths or velocities. The value of E's attraction in one second being 0.0044 ft., this difference is readily calculable in the case of the first second as follows:

$$3{,}373 \text{ feet} - \sqrt{(3{,}373 \text{ feet})^2 - (0.0044 \text{ feet})^2} = \frac{(0.0044 \text{ ft.})^2}{2 \times 3{,}373 \text{ ft.}},$$

approximately, $= 287 \times 10^{-11}$ feet.

During the second second the recession would be $2x$, or 0.0026 ft. But as this is smaller than the value



of E's attraction in the same time, the difference of the two paths would be the same as in the first second;

and similarly also in the third second, in which the total recession is only 0.0039 ft. But in the fourth second the recession is 0.0052 ft., and even if the entire attraction of E were available for the purpose it could not pull M back to the base line AC, but only to a point *c*, Bc being equal to the value of E's attraction in one second, or 0.0044 ft.

The maximum value of the diminution of M's velocity in the fourth second therefore can not exceed the difference between the lines AB and Ac. Remembering that AB in that second would be equal to the diminished velocity in the preceding second and that the angle ACB is a right angle, the difference between AB and AC may be first ascertained as follows:

$$(3373 \text{ ft.} - 3\times 287\times 10^{-11} \text{ ft.}) - \sqrt{(3373 \text{ ft.} - 3\times 287\times 10^{-11} \text{ ft.})^2 - (0.0052 \text{ ft.})^2}$$

$$= \frac{(0.0052 \text{ ft.})^2}{2(3{,}373 \text{ ft.} - 3\times 287\times 10^{-11} \text{ ft.})}, \text{ approximately, } = 4\times 10^{-9} \text{ ft.}$$

Then, having AC equal to $3{,}373 \text{ ft.} - 3\times 287\times 10^{-11} \text{ ft.} - 4\times 10^{-9} \text{ ft.}$ or, $3373 \text{ ft.} - 1261\times 10^{-11} \text{ ft.}$, to find Ac we have

$$\sqrt{(3373 \text{ ft.} - 1261\times 10^{-11} \text{ ft.})^2 + (0.0052 \text{ ft.} - 0.0044 \text{ ft.})^2}$$

and to find the difference between Ac and AB we have $(3373 \text{ ft.} - 3\times 287\times 10^{-11} \text{ ft.}) - \sqrt{(3373 \text{ ft.} - 1261\times 10^{-11} \text{ ft})^2 + (0.0008 \text{ ft.})^2}$

These may all be combined into one operation as follows: Let us call the difference between AB and Ac in the first second d_1, in the second second d_2, and so on; let the variable quantities BC and cC be denoted by m and n respectively for any and every second; and let M's velocity at the given point, 3,373 ft., be denoted by a. Then

$$d_1 = a - \sqrt{a^2 - m^2} = \frac{m^2}{2a}, \text{ approximately, } = 287 \times 10^{-11} \text{ ft.}$$

$$d_2 = a - d_1 - \sqrt{(a - d_1)^2 - m^2} = \frac{m^2}{2(a - d_1)}, \text{ approximately, } = 287 \times 10^{-11} \text{ft.}$$

$$d_3 = a - d_1 - d_2 - \sqrt{(a - d_1 - d_2)^2 - m^2} = \frac{m^2}{2(a - d_1 - d_2)}, \text{ approximately, } = 287 \times 10^{-11} \text{ ft.}$$

$$d_4 = a - d_1 - d_2 - d_3 - \sqrt{(a - d_1 - d_2 - d_3)^2 - m^2 + n^2} = \frac{m^2 - n^2}{2(a - d_1 - d_2 - d_3)}, \text{ approximately, } = 391 \times 10^{-11} \text{ ft.}$$

$$d_5 = \frac{m^2 - n^2}{2(a - d_1 - d_2 - d_3 - d_4)}, \qquad \text{approximately, } = 561 \times 10^{11} \text{ ft.}$$

. . . .

$$d_{388800} = \frac{m^2 - n^2}{2(a - d_1 - d_2 - \cdots\cdots - d_{388800})} = \quad 0.00066 \text{ ft.}$$

These approximate values are really too small, however, the 388800th term as above (the series having a common difference of 17×10^{-10}ft.) being materially smaller than that derived from the actual computation of that term. Thus in the 388800th second, m would have a value of 1166.4ft. (*i. e*, $388800x$); n 1166.3956 ft.; and assuming the entire sum of the true series to be about 330ft., $a - d_1 - d_2 - \cdots\cdots - d_{388799}$ would equal about 3043 ft. According to these values, then,

$$\frac{m^2 - n^2}{2(a - d_1 - d_2 - \cdots\cdots - d_{388800}} = \frac{1360488.96 - 1360478.69568}{2 \times 3043} = 0.0017$$

ft. This indicates a difference for the series of about 44×10^{-10}ft., instead of 17×10^{-10}ft., the variation being due to the neglect of the minus quantities in the denominator of the approximate formula, which, though negligible for a few hundreds of terms at the beginning of the series, owing to their extreme minuteness, gradually increase in value towards the end so much that they considerably diminish the value of the denominator and so increase the values of the fractions.

For the purpose of this computation, the successive diminution of M's velocity between the given points will be regarded as forming a series, the common difference of whose terms is 44×10^{-10} ft. The last term of the series is, therefore, 0.0017 ft., and the sum of all the terms of the series, or the total diminution of M's velocity at new Moon is $\frac{0.0017 \text{ ft} \times 388800}{2}$ or 330 ft., just what it was assumed to be in the preceding paragraph.

III. We have now to find the effect which these supposed diminutions of M's velocity around E would have upon the centrifugal force of M around that body. The value of E's attraction upon M at the given starting point is 0.0044 ft. per second, as already stated; and as the orbital powers are balanced at that point, M's centrifugal force there will have the same value. Then, since the centrifugal force varies as the square of the velocity, that force at the end of the first second after leaving the given starting point would be less than at that point owing to the supposed diminution (287×10^{-10} ft.) of the velocity in that second. This decrease of the centrifugal force is denoted by x in the following proportion:

$$(3373 \text{ ft.})^2 : (3373 \text{ ft.} - 287 \times 10^{-11} \text{ ft.})^2 = 0.0044 \text{ ft.} : 0.0044 \text{ ft.} - x;$$

whence $x = \frac{2(287 \times 10^{-11} \times 0.0044)}{3373}$ feet approximately, $= 75 \times 10^{-16}$ ft.

Then to the loss of velocity in the first second adding 73×10^{-10} ft., the diminution of M's velocity in the second second, the total loss of velocity in that second is 102×10^{-10} feet; and substituting this in the second term of the last proportion gives for the value of x, 265×10^{-16}ft. In a similar manner the total loss of velocity in the third second is found to be 219×10^{-10}ft., and the corresponding value of x, 570×10^{-16}ft.; in the fourth second the total loss of velocity is 380×10^{-10}ft., which gives for the value of x, 990×10^{-16}ft.; in the fifth second the total loss of velocity is 585×10^{-10}ft., and the value of x, 1525×10^{-16}ft.; and so on, the common difference of the second order of the successive values of x being 115×10^{-16}ft. According to this common difference, the 388800th term is about $\frac{(388800)^2 \times 115 \times 10^{-16}}{2}$, or 0.0008692 ft.; which may also be obtained in the same manner as each of the foregoing terms, the total loss of velocity in the 388800th second being 330 ft., which substituted in the second term of the proportion gives the more exact value of 0.000861 ft.

This would be the series of successive diminutions of M's centrifugal force around E owing to the supposed back-action of E's attraction. These diminutions of the centrifugal force, other things equal, would of course cause corresponding and equivalent excesses of E's attraction, which would tend to draw M back to E. In the first second it would be pulled back 75×10^{-16}ft., which, as in the other series, would also continue through the subsequent seconds. In the second second it would be pulled back 265×10^{-16}ft.; in the third second 570×10^{-16}ft.; and so on; the pull in each second continuing to urge M at the same rate in each subsequent second. So that, in the last second, or at new Moon, the total rate of fall towards E owing to this cause would be the sum of the falls in the several seconds. That is, the sum of the foregoing series, or approximately $\frac{115 \times 10^{-16} \text{ ft.} \times (388800)^3}{6}$, or 112 feet.

(b). *Inadequacy of the Back-Action of the Earth's*

Attraction.—Each of the first three series of perturbing forces pulled M away from E towards S; and their aggregate effect at new Moon would be to generate a velocity of M away from E of 4½ ft. + 128 ft. + 116 ft., or about 248 ft. The last series of perturbing force would oppose the combined effect of these three; but its maximum effect, as just ascertained, is considerably less than half of that due to the opposing perturbing forces. And as there is no other alleged cause, or, according to the theory of gravitation, even conceivable cause which would curb the excessive perturbing forces, M, according to that theory, would evidently keep on receding from E and towards S after new Moon was reached, with an ever-increasing velocity.

(c.) *Objections to the Back-Action Theory.*—But we are not yet done with the problem. To the first three series of perturbing forces there appears to be no serious objection whatever. They are indeed roughly computed on the basis of *average* variations of distance and velocity. But the results obtained upon this basis are very approximately correct, as various checks upon the method of computation enable us to ascertain. But the last series of perturbing forces, which it is alleged would oppose and eventually overcome the other forces, is subject to two very serious objections. The first objection to it is that the recession of M from E during any second after passing the given starting point can not possibly occasion a diminution of M's velocity around E; but would, on the contrary, necessarily imply an acceleration of that velocity and consequent increase of M's centrifugal force. The ground for this conclusion is, that, in the absence of recession, M's path would be at right angles to E's attraction. An external force then acts upon M, causing it to recede from its rectangular path. This external force acts *with* the force that maintains M's velocity, and *not* in any degree *against* that force; therefore the former can not possibly diminish the latter. And morever the external force causing the recession is clearly more powerful than any internal or opposing available force, because in spite of the latter the external force *causes M to recede*, thus asserting its superiority. It is therefore absurd to suppose that any body urged by *two* forces in the same direction will move with a *less* velocity than when the body is acted on by one of the forces only. And this argument applies not to any one particular second, but obviously to every second during which *recession* takes place.

The second objection to the last series of perturbing forces is that E's attraction was already wholly engaged in curbing M's centrifugal force, because these two forces are supposed to be exactly balanced at the starting point. So that, when the external force acts upon M, there is really *no force at all* to counteract it—no force at all to cause a back-action upon M's velocity—whereas, in the computation of the series in question, the full value of E's attraction was regarded as operating to produce that back-action. It seems certain that M's centrifugal force is neither destroyed nor diminished by the fact of M's recession from E, because, as just shown, M's velocity is neither destroyed nor diminished by that recession, and the centrifugal force depends directly upon the square of the velocity. On the contrary, it is obvious that according to the theory of gravitation, E's attraction *is diminished* upon M, owing to its recession. At the starting-point, M's centrifugal force and E's attraction were equal. After that point is passed, the centrifugal force is at least undiminished because it is aided by a new external force, while E's attraction continually declines in value owing to the recession — from all which it clearly follows that, between the given points of M's orbit, E's force of attraction is not able to cope even with M's centrifugal force. So that whatever back-action or other action E's attraction would have, would be directed wholly against M's centrifugal force; and even a surplus of the latter would still be left to aid the external perturbing force, with no force whatever to act in opposition.

If these objections are valid, as they certainly appear to be, then it follows that the last computed series of perturbing forces loses all semblance of logical foundation as a force drawing M towards E and becomes changed into another which would draw M away from E and therefore in harmony with the other three forces acting in that direction. But even if, owing to any cause whatever, these objections should prove to be invalid and the last series be legitimately derived, it still remains that that series is utterly inadequate to cope with the other three perturbing forces; so that in any case the ultimate result would be the same—a rapidly accelerating recession of M away from E and towards S, after new Moon was passed.

(d). *Front-Action of the Sun's Attraction.*—But if these objections are invalid,then there appears another horn to the dilemma. If the last computed series of perturbing forces legitimately applies to M in the given case, then there would certainly apply in the same case still another and far more powerful perturbing force than any we have yet computed, which would act in opposition to the perturbing force due to the back action of E's attraction. This new perturbing force would be caused by the *front-action of the Sun*. In the given case, M is, as it were, between two fires. While it recedes from E on the one hand, it approaches S on the other; and if the attraction of E acting *against* M's motion diminishes its velocity, then the attraction of S acting *with* M's motion would very obviously increase that velocity. It is true that the attraction of S has to contend with the centrifugal force of M in its solar orbit; but it is equally true that E's attraction has to contend with M's centrifugal force in its terrestrial orbit. So if the latter attraction produces an effect upon M's velocity, there appears to be no reason whatever why the former attraction should not also produce an effect upon M's velocity. To begin with, M's path in the given case is oblique or inclined *towards* S in a much greater degree than it is inclined *from* E; and, moreover, as the attraction of S is about 2½ times as powerful as that of E, it is not very difficult to see that the back-action of the latter would be very small indeed as compared with the front-action of the former; so that (even if it were regarded as properly applicable to the case) it would be a mere waste of space and time to compute the actual value of this new perturbing factor for the purpose of adding its preponderating effect to the effects of already preponderating factors.

80. *Direct Contradiction of the Theory by the Facts.*—From all points of view, then, we find that according to the theory of gravitation, the great preponderance at least, and apparently all, of the perturbing forces upon the Moon, in the given case, tend to draw that body away from the Earth and towards the Sun; which tendency rapidly increases as new Moon, or the apogeeal point, is approached.

At the given starting-point the orbital forces upon the Moon around the Earth are so adjusted that there is no perturbing force whatever, tending to draw the latter either from, or towards, the former. Prof. Proctor says that at the given point the perturbing force is *wholly tangential*, *i. e.*, tending to draw the Moon along the tangent to its orbit around the Earth, and therefore in a direction *at right angles* to that of the Earth's attraction. The Moon is also assumed to be at its mean distance from the Earth at this point, so that the Earth's attraction and the Moon's centrifugal force are about balanced. In fact we *know* that at the given point the orbital forces upon the Moon at least *do not urge that body towards the Earth, because we actually observe that the Moon moves away from the Earth after leaving the given point.* Now after leaving the given point, new perturbing forces have been shown to arise, which would urge the Moon away from the Earth; and these forces continually increase in amount as the Moon's distance from the point increases, until at new Moon these perturbing forces become thousands of times more powerful than all the other orbital forces upon the Moon combined. Therefore, unless there should exist some perturbing force or forces which would all along counteract these perturbing forces so as to prevent them from getting such headway, it is manifest that the Moon's motion, according to the theory of gravitation, would be very little better ordered than those of the moon of Mr. Artemus Ward. Yet, after a dilligent search for such counteracting perturbing forces in every indicated and conceivable quarter, we have found instead only still greater and more powerful forces conspiring to derange the Moon's motions still more—conspiring to drag the Moon, nolens volens, away from the

Earth at syzygy and into the arms of the Sun. So that the returning of the Moon backwards around the Earth and from the Sun, which we actually observe to take place, would be a physical impossibility in accordance with that theory.

81. *Possibility of the Given Case.*—In concluding the discussion of this problem a few words may be said regarding the possibility of the given case. It is, of course, a well-known fact that the apogee of the Moon's orbit is not a fixed point, with respect either to the Earth or to the Sun, but a point which itself moves around in the orbit, although more slowly than the Moon. Its rate of motion is, in fact, nearly 41° per annum; so that the periods between successive conjunctions of apogee with the Sun is a trifle less than 412 days.* During every such period, then, the apogeeal point moves slowly from new Moon around through every point of the Moon's synodic orbit back again to new Moon. If further evidence were necessary to show that the apogeeal point may lie at new Moon, we have it in the fact of annular eclipses of the Sun. Solar eclipses happen at new Moon; and ordinarily the distance of the latter from the Earth is such that the Moon's disc will totally cover and hide the Sun from the view of an observer in the line of the Moon's shadow. But when the apogee of the Moon's orbit is at new Moon, and the conditions are such that the latter will pass over the Sun's disc at that time, the distance of the Moon from the Earth will be so great that only the central portion of that disc will be covered by the Moon and the outer rim of the Sun will be visible all around the lunar disc; whence the name, annular eclipses. These annular eclipses prove, there-

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*R. A. Proctor, *The Moon*, p. 394.

fore, that the Moon's apogee, or point of greatest distance from the Earth, occasionally lies at new Moon, as has been assumed in the given case, because it is only the Moon's greatest distance at new Moon that can cause such eclipses. This and the balancement of the orbital forces upon the Moon at the given starting point are the essential points of the case. The given distance of the Moon at that point is not an essential element; as any other possible distance at that point would not appreciably change the results obtained.

As to the equilibrium of the orbital forces at the given starting-point, it may be stated here that only the *normal components* of the perturbing forces upon the Moon, that is, those components which cause the Moon to recede from, or approach towards, the Earth are said to be balanced upon the Moon at that point. The *tangential components* of the perturbing forces, that is, the components which *accelerate* the Moon's motion around the Earth, are stated by both Herschel and Proctor to be nearly at a maximum at that point. It is very manifest, however, that this condition of things is by no means unfavorable to the conclusions here arrived at.

82. *Previous Discussions of the problem.*—It may appear strange to the reader that no computation of the perturbing forces upon the Moon by other authorities has here been referred to. But where, it may be asked, are such computations to be found? Inquiries regarding this subject have been sent to various observatories and scientific journals, and the answers received to these inquiries indicate that no such computations are anywhere in existence. As a sample of these answers I quote from Mr. G. W. Hill of the Naval Observatory, Washington, D. C., upon this subject: "I do not know any more accurate values of the

quantities you ask for than those given by Mr. Proctor. They do not particularly interest the mathematical astromer as he has no use for them. Hence, they have never been computed with the last degree of precision. Their computation is sufficiently laborious . . . . and two months' work would be necessary to get them with all possible exactitude.

"No exhaustive treatise on the lunar theory exists in the English language. Perhaps the translation of Laplace's *Mecanique Celeste* by Dr. N. Bowditch comes the nearest to it." Laplace and Mr. Proctor, however, treat only of the general problem and do not discuss the perturbing forces upon the Moon in detail. Newton gives the mean value of the solar perturbing force upon the Moon as $\frac{1}{638000}$ of gravity at the Earth's surface, or $\frac{1}{179}$ of the principal force which holds the Moon in its orbit. Herschel gives the ratio of the solar perturbing force to the central force holding the Moon in its terrestrial orbit for three positions of the perturbed body, or full Moon, last quarter, and new Moon, as 1 : 90, 1 : 179, and 1 : 89, respectively. He also represents by means of lines of various lengths the values of the perturbing force at intermediate positions. But he makes no attempt to compute the *continuous effect* of these values of the perturbing force. And Mr. Proctor, one of the most recent authorities on the subject, and in a volume devoted wholly to our satellite, follows very closely in the footsteps of Herschel and Newton. All of these astronomers appear to notice only *one* factor of the perturbing force upon the Moon, namely, that due to the distance-variation of the perturbed from the perturbing body. The more powerful factors due to the distance-variation of the Moon from the Earth and to the variation of the Moon's velocity around the

Sun are ignored, and no reference whatever is made to any work where these ignored factors are discussed, or where the continuous effect of the factor, the separate values of which are given, is carried out consecutively and cumulatively through the successive time-units during which it acts.*

83. *The Alleged Perfection of the Theory.*—Now if it be true, as indeed it has every appearance of being, that the actual amounts of the perturbing forces upon the Moon in its orbit around the Earth, and their true cumulative effects in the acknowledged periods of their action, according to the theory of gravitation, have never been computed; it seems very remarkable, to say the least, that that theory should be regarded, as it certainly is, by the most eminent scientists and mathematicians, as all but fully, if not indeed completely, demonstrated. The following utterance by Sir John Herschel, for example, is evidently intended to convey the impression that the theory of gravitation accounts completely for every item of force or motion to which the Moon is subject at any time or during any period of time:—"What Newton left undone, however, his successors have accomplished; and at this day it is hardly

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* The lunar theory is also discussed by Airy in his work on "Gravitation." Hugh Godfrey has published a brief elementary book, and Prof. John N. Stockwell a larger volume upon this subject. But these works, like those of Laplace, Newton, Herschel and Proctor, treat only the general problem and do not attempt to give the cumulative effect of all or any portion of the perturbing forces here considered for the entire periods of their action. Probably the best treatises on the subject are in French, German and Latin. Some of them are: by Plana, "*Théorié du Mouvement de la Lune*," 1832; by Delauney, *Théorié du Mouvement de la Lune*, Tomes xxviii and xxix, of the Memoirs of the Paris Academy of Sciences; by P. A. Hansen, "*Fundamenta Nova Investigationes Orbitae quam Luna Perlustrat*," 1834; and by the same author, "*Darlegung*," etc., 1864. These works I have not seen, but have been informed that they chiefly relate to secular variations of the Moon's motion, such as recession of the nodes, change of inclination of orbital plane, annual equation, secular acceleration, parallactic inequality, evection and general consideration of all the disturbing forces upon the Moon.

too much to assert that there is not a single perturbation, great or small, which observation has become precise enough clearly to detect and place in evidence, which has not been traced up to its origin in the mutual parts of our system, and minutely accounted for in its numerical amount and value by strict calculation on Newton's principles." This passage also appears to indicate the method or system of the mathematical astronomer. In fact, this method seems to be first of all to *observe the perturbation*, and *then* to account for it by the theory of gravitation. This is the method, which it appears, that all writers on the subject have followed; and hence it is that such perturbations as are *not* observed, but which yet the theory seems clearly to involve, and in cases of very common occurrence, are rarely, if ever, even mentioned by these writers.

CHAPTER IV.

THE AMOUNT AND DISTRIBUTION OF THE SUN'S HEAT.

84. *The Temperature of the Sun's Surface.*—Passing over a large number of objections which have already been urged by other writers against the mechanism of our system as explicable by the theory of gravitation, let us now give attention for a moment to the amount and distribution of the Sun's heat, which that theory involves, and compare it with the state of things which appears to be indicated by actual observation.

According to the present theory, the Sun's heat radiates equally in all directions outwards from that body. The quantity of solar heat which would be intercepted by the Earth, therefore, would be such a part of the whole heat radiated from the Sun as the apparent angular area of the Earth as viewed from the Sun's center is of the area of the whole sky. Now, the angular diameter of the Earth, as it would be seen from the Sun is only about 17 seconds; and, as similar areas are to each other as the squares of their like dimensions, the angular area of the Earth, viewed from the Sun, will be to that of the whole sky as $(17)^2$ is to $2(180\times60\times60)^2$, or about as 1 to 2,900,000,000; so that only $\frac{1}{2900000000}$ of the heat radiated from the Sun falls upon the Earth. Then as the Sun's angular diameter from the Earth is about 31 minutes of arc, the Sun's area as compared with that of the Earth will be about as $(31\times60)^2$ to $(17)^2$ or about as 12000 to 1. Therefore the heat radiated from a certain area of the Sun, as a square inch or a square yard, is $\frac{2900000000}{12000}$, or about 240000 times greater than that which is received from the Sun upon an equal area on the Earth. Now we may take the Earth's surface temperature exposed to the Sun at the Equator at about 150° F. above zero, and this acording to Langley is about $\frac{3}{5}$ of the solar heat received at the outer limits of the Earth's atmosphere. It is also supposed that if the Sun were suddenly blotted out of existence, the Earth's surface temperature at the Equator would drop down, according to Prof. Langley and others, to some 300° or 400° below zero, F. So that the quantity of heat received upon the Earth, which is due to the Sun's radiation is such as would raise its normally exposed surface about 600° F. And as the amount of heat radiated from a certain area of the Sun is 240000 times greater than that received upon an equal area of the Earth, the Sun's temperature ought to be about 600° × 240000, or 144,000,000° F. This is about the same reasoning as Newton employed regarding this subject; and the result above obtained is not very greatly different from Newton's result. This would make the immediate neighborhood of the Sun so extremely heated that all known substances traversing it would be reduced to vapor. Therefore, when the comet of 1680 passed so close to the Sun as to almost graze its atmosphere, Newton was very much surprised indeed when that body which remained in the immediate neighborhood of the Sun for many hours, brushed around and passed the great luminary without undergoing the slightest noticeable change, although, according to his own computation, the comet must have been subjected during that time to a degree of heat 2000 times that of red-hot iron.

Whether this circumstance staggered his belief in the extremely elevated temperature which he had deduced for the Sun, or not, it, together with many other circumstances, certainly staggered others in that belief, and as a consequence there is to-day probably a score of different estimates of the Sun's temperature from several million degrees down to as low as three thousand. On this subject, Mr. J. Norman Lockyer says: "The values that have been suggested by various men of science vary between 18,000,000° and 3,000°. You may take your choice. The fact is, I think, that we are not yet in a position to find out the very best method of determining the temperature and thus marking it down in a perfect manner, for the reason that the more one knows about the problem, the more one sees how terribly complicated it is."*

The lowest of these values are not those which have

Nature, XXXIII, 402.

been determined in accordance with the theory of gravitation, but those which have been determined from comparisons with actual temperatures upon the Earth, or by means of the spectroscope. Thus Prof. S. P. Langley made direct comparison of the Sun's heat with that of the superheated metal at a "pour" of the Bessemer converter. From this he states that "the heat from any single square foot of the Sun's surface was found to be *at least* eighty-seven times that from a square foot of the melted metal." He further adds—"It is probable from all experiments made up to this date that the solar effective temperature is not less than 3,000 nor more than 30,000 degrees of the Centigrade thermometer. Sir William Siemens, whose opinion on any question as to heat is entitled to great respect, thought the lower value nearer the truth."* Here, then, appears to be a direct conflict of actual observation with the theory.

85. *Unvarying Quantity of Solar Heat at Various Distances from the Sun.*—But a more serious conflict of actual observation with the theory is found in the *constancy of the amount of solar heat* which falls upon the Earth at *various distances* from the Sun. It is well known that the Earth is some three millions of miles nearer to the Sun in January than in July. According to the theory of gravitation, it is shown by Sir John Herschel that "the least variation of temperature under such circumstances which can reasonably be attributed to the actual variation of the Sun's distance is 23° F."† The summers of the Southern hemisphere, therefore, should be at least 23° hotter than ours on the average, and the winters of the Southern hemisphere colder than ours by the same difference. Yet the

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* *Century Mag.*, December, 1884.

† *Outlines of Astron.*, Art. 369 a.

eminent Sir William Thomson tells us[*] that "neither at the equator nor in the southern or northern hemisphere has this difference been discovered by experience or general observation of any kind." This is certainly vital evidence, and it goes remarkably direct against the theory of gravitation.

86. *Amount of Solar Heat Falling Upon Either Pole of the Earth During its Summer Season Greater than that upon a Point at the Equator.*—In still another instance is the amount of sunheat which would be received upon the Earth in accordance with the theory of gravitation, glaringly at variance with the observed facts. That the temperature of the North Frigid Zone during our summer is a great deal lower than at the Equator, is so commonplace a fact that it seems almost puerile to mention it. Yet we have it upon the authority of Dr. Zenker, in a work which has been awarded a prize by the Paris Academy, that, "leaving the air out of account, as has usually been the case, . . . the heat received by the Pole on a summer day is greater than that which falls on a point at the equator. Thus, taking as unit, the heat received during twenty-four hours by a place at which the sun is in the zenith, the North Pole receives an amount of heat represented by 0.397, and a point on the equator an amount represented by 0.292."[†]

In other words, there would fall upon the North Pole, according to the present theory, an amount of solar heat greater by over one third than that which would fall upon a point at the Equator! Paradoxical as this may at first sight appear, it readily admits of a simple explanation. For, during our summer season, the Sun's rays are at no time perpendicular to the

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[*] *Nature* XXXV, 297. [†] *Nature*, XXXVII, 552.

Equator, the average inclination of these rays to a point upon the equatorial surface while exposed to the solar heat being considerably more than half as great as the average inclination to the polar surface; and also the equatorial surface receives the Sun's rays for little more than half of every twenty-four hours, while the polar surface receives the Sun's rays during the entire summer without intermission. Why, then, is it not warmer at the polar regions than at the equatorial regions, to correspond with the greater amount of solar heat which theoretically falls upon the former place? Some are inclined to think that the reason is, the Sun's rays which fall upon the Pole, having the greater inclination, and consequently having to pass through the greater thickness of atmosphere, would be more absorbed by the air before reaching that surface. But this view is open to the very serious objection that the absorption and accumulation of the solar heat by the atmosphere is the very thing that raises the temperature at the Earth's surface; for if there were no atmosphere at all to absorb and retain the Sun's heat, the temperature of the Earth's surface would be some hundreds of degrees below zero, even under a vertical sun. An excellent authority on this subject says: "Although the actual solar radiation is thus largely increased, yet the temperature of the Earth's surface is not due principally to this direct radiation, but to the quality of selective absorption in our atmosphere. *Without which the temperature of the soil in the tropics under a vertical sun would probably not rise above*—200°C. Nearly all the 215 or more degrees of difference between this and the actual mean temperature of the planet's surface is due to this selective absorption, which accumulates the heat, though in a manner which has not been hitherto correctly understood. It should be understood that these researches have had a practical bearing of great consequence. The temperature of this planet, and with it the existence not only of the human race, but of all organized life on the globe appears, in the light of the conclusions reached by the Mount Whitney expedition, to depend far less on the direct solar heat than on the hitherto too little regarded quality of *selective* absorption in our atmosphere which we are now studying."* From this it seems quite clear, then, that the greater the amount of heat that was absorbed by the atmosphere of a region, the warmer the temperature of that region ought to be. For the same writer adds: "Generally speaking, the radiation that we see enter, we see escape within the utmost limit of the known solar spectrum," according to which the radiation which the atmosphere absorbs and stores up is all that remains and is very obviously that to which almost alone the surface temperature is due.

Still another explanation of the extremely low temperature which is known to prevail at the polar regions as compared with that at the equatorial regions, in spite of the greater amount of solar radiation and atmospheric absorption at the former which the theory implies—is that, in these regions, *the ice and snow reflect the heat falling upon them* to a much greater extent than the land surface of the equatorial regions does. It really seems that this attempt at explanation must have been made because there was none better to offer. We need not discuss all the objections that could be made to this alleged explanation. An insuperable objection to it is involved in the single question—If

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*S. P. Langley, *Researches on Solar Heat, Prof. Papers No. XV.* U. S. Sig. Service, p. 213.

there is a greater solar radiation and atmospheric absorption at the polar regions than at lower latitudes, as Dr. Zenker shows, why is not the snow and ice melted away at the former place as it is in the latter upon the approach of our summer season? In latitude 40°, *e. g.*, tracts of country fully as large as Greenland is frequently covered with ice and snow; yet a very few warm days of spring (not to mention the summer at all) is sufficient to melt it all away; while the ice and snow of Greenland, where the amount of solar radiation is theoretically much greater, scarcely melts at all! It is true that a considerable amount of snow and ice would accumulate in the Arctic regions during our winter; but it is equally true that, if all the ice and snow of Greenland were removed down to latitude 40° and spread over that country to the same depth, it would all melt away during a single month of summer*; and yet, according to the current theory, a much less amount of solar heat is available to melt the ice and snow in latitude 40° than in northern Greenland.

87. *Direct Contradiction of the Theory by the Facts.*—It follows, therefore, that both the temperature of the Sun's surface and the distribution of the solar radiation, which the current theory clearly involves, is emphatically contradicted by actual observation. The degree of heat at the Sun's surface which

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*Langley computes from his researches that the solar heat received upon the outer limits of our atmosphere is such as would melt an ice-sheet 178 feet thick annually over the entire surface of the Earth; and he further finds that only one-third of this heat is absorbed by the atmosphere from a vertical Sun. Of course, then, a much greater thickness of ice would *actually* be melted at the Equator during even a single summer, because the temperature there is much above the average temperature of the Earth's surface; and, *theoretically*, a still greater thickness should be melted at the Pole during the same time because a greater amount of solar radiation theoretically falls and is retained there.

that theory undoubtedly implies is, in the first place, almost inconceivably great; in the second place, it is belied by the presence of black spots on the Sun's surface, which are generally admitted to be formed by the down-rush of *cooled*, *solid* particles, whereas the theoretical temperature of the Sun is such as would almost instantly dissolve all known substances into vapor, even at a distance of millions of miles from the Sun's surface; in the third place, it is belied by the impunity with which the comet of 1680 passed through the immediate neighborhood of the Sun; in the fourth place, it is belied by comparison with known temperatures upon the Earth's surface; in the fifth place, the distribution of the solar heat which the theory involves is belied by the utter absence of those very considerable differences of temperature upon the Earth, which should theoretically accompany its varying distances from the Sun; and in the sixth place, the theoretical distribution of the solar heat over the Earth's surface is almost diametrically the opposite of that which we actually observe.

CHAPTER V.

THE OCEANIC TIDES.

88. *The Tidal Theory.*—But perhaps the most glaring instance of incongruity of the theory of gravitation with the actual facts, is furnished by the phenomena of the tides. According to that theory, the Moon is the chief tide-producer; and the alleged cause of the tides is the difference between the Moon's attrac-

tion at the center of the Earth and the two points of the Earth's surface which is nearest to, and farthest from, our satellite. Thus on the side of the Earth nearest to the Moon, the Moon's attraction would be *greater* than at the Earth's center because the distance in the former case is less than in the latter; and therefore the water on that side of the Earth would be drawn away from the Earth's center, thus causing the *tide*. Also the Moon's attraction would be *less* upon the farthest side of the Earth from the Moon than upon the Earth's center, because the distance in the former case is *greater* than in the latter; and therefore the Earth's center would be drawn away from the water on that side, which would thus bulge away from the Earth's center and cause the *antitide*. This is the theory; and this theory might do, perhaps, if it were not for one or two very important factors, which appear to be wholly ignored by it.

89. *The Tide-Raising Force Directly Opposed by Terrestrial Gravity.*—One of these factors is the attraction of the Earth itself upon its surface waters. This attraction holds these waters to the Earth's center with a force or power more than twelve million times greater than the alleged force which would pull them away from the Earth's center. Does it not really seem, even to the most casual reader, that it would be utterly impossible for this very minute force to pull the waters away from the Earth's center, in direct opposition to the immensely more powerful force holding the waters to that center? And does it not really seem, also, that this impossibility is a vital objection to the current tidal theory?

This impossibility appears to be so self-evident and axiomatic, that it is really difficult to present the objection in plainer words. If, however, we suppose that twelve million horses were pulling a car in one direction and a single horse pulling it in the opposite direction, it would seem very plain to us that the car would not move in the direction of the single horse. Nor would the case be altered in the least, if we should suppose that a physical obstruction, aside from the single horse, prevented the car from moving in the direction in which the many horses pulled it, with no obstruction whatever, aside from the many horses, to prevent it from moving in the direction of the single horse. In this last case, it is just as obvious that the millions of horses would hold the car against the obstruction, from which therefore it would be quite impossible for the single horse to pull it away in his own direction. Now the car represents the water on the Earth's surface; the twelve million horses pulling the car in one direction represents the Earth's attraction pulling the waters towards the Earth's center; the one horse pulling the car in the opposite direction is the difference of the Moon's attraction upon the central mass and either side of the Earth in the line of the two bodies, pulling the waters from the Earth's center; and the obstruction which prevents the many horses from moving the car in their direction represents the solid surface crust of the Earth, which prevents the falling of the waters towards the Earth's center.

Is it reasonable, then, that the one horse-power can raise the waters in the least degree away from the Earth's center in direct opposition to the united pull of the twelve million horse-power towards the Earth's center? This appears to be an extremly simple mechanical problem. Yet apparently in the face of all sense, reason, and experience, the theory of gravitation alleges that the one horse-power actually pulls the water from the obstruction against which the united strength of twelve million horse-power is continually holding it.

The reasonable view of this case would seem to be that the one unit of power pulling away from the Earth's center would counteract the effect of one of the twelve million units of power pulling in the opposite direction, thus leaving a balance of 11,999,999 units of power pulling towards the Earth's center. But while this would diminish the pull upon the waters towards the latter point in a very slight degree, yet very obviously the waters would still be held almost as strongly as ever towards that point with nothing at all now to pull them away from it.

90. *The Tides not Raised Where the Alleged Tide-Raising Force is Applied.*—While the absurdity of the gravitational theory of the origin of the tidal wave is thus shown as clearly, it seems, as anything can possibly be made, yet this absurdity appears to be still further enhanced by the well-known fact that the actual tidal wave rarely, if ever, is raised, or appears, directly under the Moon, but generally at a portion of the Earth's surface 90° from that at which the Moon is in the meridian. How the Moon's attraction can thus raise the waters in a direction at right angles to its own and where no tide-raising force whatever theoretically applies, is—simply inexplicable. It would seem that if it were the Moon's attraction that raised the tidal wave directly towards, or indirectly from, itself, in the open ocean at least that tidal wave would be directly underneath the Moon's orb, and that, if for any reason, the wave were delayed a considerable distance behind that position, it would gradually die out,

simply on account of the friction it has to encounter and the absence of any cause to sustain it in its displaced position. But, wonderful to relate, we have it on the authority of the theory of gravitation that the tidal wave generated by the transit of the tide-producer over a certain meridian of the tide-bearer may not itself arrive at that meridian until some one or two days have elapsed after the transit which caused it! "The interval of time between the transit of the moon which originates a tide and the appearance of the tide itself, is called the age or retardation of the tide. .... The age of the tide is, from the times, 39½ hrs., from the heights, 42½ hrs."*

91. *The Oceanic Tides Obliterated by Tides in the Earth's Interior.*—Another vital objection to the present theory of the tides is that, according to the generally believed physical condition of the Earth, there would be no tide at all. Strange as this may appear, it is nevertheless true, as the following considerations go to prove. It is a well known fact that the temperature of the Earth's crust increases about 1° for every 50 feet below the surface. This uniform increase of temperature with depth is found at all points of the surface without any respect to the sea-level, and is therefore a general characteristic of the Earth's crust. This temperature gradient obviously implies a constant transfer of heat from warmer inner strata to cooler outer strata by conduction; according to which the difference of temperature would soon disappear by the warmer strata cooling off if there were not a constant supply of heat within the Earth. And this proves that the rise of temperature thus maintained for unknown millions of

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*Orray Taft Sherman. *Meteorological and Physical Observations on the E. Coast of British America: Prof. Pap. U. S. Sig. Ser.*, No. XI, p. 28.

years is not merely superficial, but continues to a very great depth. Now this rate of increase implies a temperature of about 1,600° at a depth of 15 miles; a temperature sufficient to reduce to the fluid state all of the known materials which form the solid crust of the globe. The apparently solid Earth on which we live is therefore a comparatively thin shell of solid matter inside of which is enclosed the vast bulk of the Earth in a molten or gaseous state. Many facts are observed to corroborate this conclusion; among which are boiling springs, earthquakes, and volcanoes; the torrents of lava or melted rock from the latter for thousands of years clearly testifying to the molten condition of the Earth's interior.

But how is this state of things to be reconciled with the present theory of the tides? If the interior of the Earth is in a molten state, it is very clear that in accordance with the theory of gravitation, a tidal swell would be caused there just as well as at the surface of the crust. This tidal swell would cause the thin crust to be successively elevated and depressed; and these successive bendings of the crust would neutralize the effects of the ocean tides because the bottom of the sea would be raised almost, if not quite, as much as its surface, and the depth of the sea would thus remain almost unchanged, and consequently no tide would be observed.

92. *Other Objections Elsewhere Noticed.*— We have thus briefly noticed a few important objections to the current theory of cosmical mechanics. Other objections might be urged against that theory; but it seems quite unnecessary to multiply instances further. The utterance of Huxley holds in this theory, as in every other theory :—" One fact with which it is positively

inconsistent is worth as much, and as powerful in negativing the hypothesis, as five hundred."

We may now retrace our steps and go over the same ground again in the light of the new theory, which we have already briefly introduced, in order to observe the simple explanations which is furnished not only of these phenomena in which the current theory fails, but also of many other phenomena of cosmical evolution. Numerous minor objections to the current theory will be noticed as the exposition of the new theory proceeds.

PART III.

A NEW THEORY.

What there is between the sun and the planet that makes each of them pull the other, Newton did not know; nobody knows to this day; and all we are now able to assert positively is that the known motion of the planet is precisely what would be produced if it were fastened to the sun by an elastic string, having a certain law of elasticity.

Prof. William Kingdon Clifford.

Theoriarum vires, arcta et quasi se mutuo sustinente partium adaptatione quâ, quasi in orbem cohaerent, firmantur. *

Bacon.

* The strength of theories is established by their compact and mutually sustaining co-adaptation of parts by which they cohere as in an arch.

CHAPTER I.

EVOLUTION OF THE SOLAR SYSTEM.

93. *The Original Solar Spheroid.*—The primary conceptions of the new theory are little different from those of the nebular hypothesis. These conceptions are that the Solar System was once a vast rotating spheroid of vapor, nearly or quite homogeneous, the equator of which probably extended outwards on all sides nearly to Neptune's orbit; and that this vapor was made up of minute, but distinct, component parts, having some *material* connexion with one another by virtue of which the vapor would cohere within certain limits, and its component parts, if unrestrained, would tend to lessen the distance between them. This tendency

of the component parts to approach one another may seem not unlike the attraction of gravity; but the two are not necessarily identical. There are other agencies that cause approximation of parts besides gravity, such, *e. g.*, as magnetism, elasticity, and loss of heat. The connexions here premised between the ultimate components of the vapor, and tending to hold or approximate the parts to each other, are supposed to be highly elastic, and, in support of this view, it may be mentioned here that Newton and Faraday have thought that gravitation itself would find its true explanation by means of some such *material* agency as is here conceived. As to whether the original solar spheroid was intensely heated, or even heated at all in the ordinary sense of that word, nothing can be stated with certainty. Heat is a mode of motion, and subsequent pages may show to us that there are many degrees, or different modes, of such motion, forming a regular series, similar to the wave-lengths of the solar spectrum, of which the modes that are sensible to us may be comparatively few, and belonging, perhaps, to the middle portion. It may not be impossible, therefore, that, if the processes by which bodies become to us intensely heated were further intensified to a certain degree, the resulting mode of motion would no longer be sensible to us as heat, and it may even be possible that, if the intensification of the heating process were sufficiently great, the resulting mode of motion would not be sensible to us at all. It seems not unreasonable to suppose that this last condition would be that of the original solar spheroid, the intensity of the process to which it must have been subjected being such as to reduce its density probably far below that of the most perfect vacuum that man can produce.

The rotation of the spheroid will be referred to and explained in a more advanced stage of the discussion.

94. *Surface Contraction and Development.*—Our premises, then, once more, are a vast rotating spheroid of vapor, nearly or quite homogeneous, and made up of minute parts having connexions between them, by virtue of which the mass coheres, and, under certain circumstances, the parts may approach one another. From these premises it would follow that those parts situated on the surface of the sphere would have the greater liberty of action, because they are not influenced by other parts upon their outer sides, while the subjacent parts are thus influenced on all sides. For this reason, these surface parts would tend to approach their subjacent neighbors and form with them a closer union. What the nature of this union would be, we can not undertake to state; but we may suppose that the two adjacent layers of surface parts would eventually join together in forming consolidated groups of component parts, which we may designate by the term *molecules*, each molecule being connected with its neighbor, much in the same manner as the primordial parts, save that the connexions of the molecules may be more complex. This change in the structure of the two surface layers from approximate homogeneity to comparative heterogeneity would allow to the third layer a greater liberty of inward motion; and this layer, or some of its component parts, would tend to approach the fourth layer of component parts, though perhaps more slowly than the parts of the first layer. Thus would be formed a second layer of molecules; and in much the same manner would be formed a third, a fourth, a fifth, layer of molecules, though quite probably each successive layer, owing to the influence of the outer heterogeneous lay-

ers, would require a much greater time to form than the preceding layer. Now the same causes that made the original surface components approach their subjacent neighbors would also operate upon the surface molecules. These would approach the second layer of molecules and form with them a layer of compound molecules, having still more complex relations with the simpler molecules and with one another. And so also with a third and fourth layer of molecules. In the same manner also would be formed still more compound molecules; and we apparently have no reason to suppose that this process would not continue, or to draw a limit beyond which, if left to itself, it would cease.

We may corroborate and further illustrate our views thus far by the following instructive extract from the presidential address of Prof. William Crookes at the fifty-sixth annual meeting of the British Association: "In course of time, some process akin to cooling, probably internal, reduces the temperature of the cosmic *protyle* to a point at which the first steps in granulation take place; matter as we know it comes into existence, and atoms are formed. As soon as an atom is formed out of *protyle* it is a store of energy, potential (from its tendency to coalesce with other atoms by gravitation or chemically) and kinetic (from its internal motions). To obtain this energy, the neighboring *protyle* must be refrigerated by it, and thereby the subsequent formation of other atoms will be accelerated. But with atomic matter the various forms of energy which require matter to render them evident begin to act; and, amongst others, that form of energy which has for one of its factors what we now call *atomic weight*. Let us assume that the elementary *protyle* contains within itself the potentiality of every possible combining proportion or atomic weight. Let it be granted that the whole of our known elements were not at this epoch simultaneously created. The easiest formed element, the one most nearly allied to the *protyle* in simplicity, is first born. Hydrogen—or shall we say helium?—of all the known elements the one of simplest structure and lowest atomic weight, is the first to come into being. For some time hydrogen would be the only form of matter (as we now know it) in existence, and between hydrogen and the next formed element there would be a considerable gap in time, during the latter part of which the element next in order of simplicity would be slowly approaching its birth-point; pending this period we may suppose that the evolutionary process, which soon was to determine the birth of the new element, would also determine its atomic weight, its affinities, and its chemical position.

"In the original genesis, the longer the time occupied in that portion of the cooling down during which the hardening of the *protyle* into atoms took place, the more sharply defined would be the resulting elements; and, on the other hand, with more irregularity in the original cooling we should have a nearer approach to the state of the elemental family and as we know it at present."

95. *Surface Rigidity and Ring-Formation.*—The sphere is premised to have a rotatory motion; and this motion would have some effect upon the molecules. These bodies, owing to the approach of their constituent parts, would obviously be much denser than the original vapor; and it is well-known to us that in a revolving mass, when the constituent particles have freedom of motion, the denser of them will invariably seek the circumference. Moreover, there would be a

movement of the molecules towards that portion of the circumference having the greatest amount of motion; *i. e.*, the equator of the spheroid. For if we are allowed to judge from analogy, the connexions of the primordial molecules and atoms would be readily transferable from one to another, even far more so than in the case of gases or vapors upon the Earth. So that these developed molecules would glide slowly over their subjacent neighbors towards the more swiftly rotating equatorial regions. In course of ages a ring of compound particles would thus aggregate near the equator; and, at the same time, the surface development would be continually progressing, both inwards into the sphere and into greater and greater complexity of surface structure. As already intimated, there does not appear to be any reason whatever for assigning any particular limit to this development. And it seems evident that its uninterrupted continuance would eventually result in a rigidity of the surface matter, particularly at the equator, where the developed structure would be much the thickest. The rigidity would spread slowly from the equator to the poles; the internal development still going on, and the equatorial flow of compound molecules taking place on the inside of the rigid structure.

The rigidity, increasing with increasing thickness, would eventually resist further contraction at the equator; the less rigid polar regions still following the contracting body of the sphere, in obedience to its connexions with that body. But the rigidity would continually spread towards the poles, thus gradually forming a solid ring concave to the sphere, the concavity being filled with partially developed original vapor.

At this stage, probably, as the sphere contracts its volume, a space would be formed between it and the ring. The molecular connexions between the two would become elongated and refined in the vast laboratory; their tension, as the space widens, being relieved by the addition of the gaseous atoms or molecules of the sphere.

96. *Ring-Separation.*—It seems probable that the polar regions, having previously become rigid, but having the weaker crust, would eventually begin slowly to fracture and bend inwards owing to the continual strain upon their connexions with the sphere; and at the same time the equatorial portion of the ring would slowly move outwards owing to its rotation, thus gradually stretching itself to a greater diameter and depth and lessening its thickness. Both the fracture and the expansion might at first be extremely slow—far more so perhaps than the gradual sinking or elevation of certain portions of the Earth which geology brings to our notice; and which is generally no greater in amount than an inch or two in a century. But the process would continue; and in the course of a very great lapse of time, the ring would have separated wholly from the sphere, save for the inchoate connexion or bond of attachment between the two bodies. Before the separation of the ring from the sphere, but during the process in which the separation culminated, the polar regions of the original crust, still adhering to the surface of the sphere, would approach more and more towards the equator as the equatorial portion continually recedes by the centrifugal tension of the ring itself and the increasing contraction of the sphere. So that, at the point of separation, the ring would be a broad and flat body lying in the sphere's equatorial plane; in which plane its thickness, would be about

double the thickness of the original crust; the greatest material thickness of the ring being obviously at its outer edge, where the crust was originally the thickest.

97. *Disruption of the Ring Into the Planetary Form.*—It may chance that some sudden violence of the polar fractures of the crust, as the projection of the ring proceeds, would cause the collapse of the whole equatorial crust, upon itself;—upon itself partly because the molecular connexions generated in the developed structure of the crust would reasonably be much more powerful than the connexions between the crust and the undeveloped sphere; and partly for reasons to be noticed farther on. If any violence of the polar fractures does not occur to disrupt it (which it seems would generally be the case owing to the extreme slowness of their occurrence), the ring would continue to expand its circumference diminishing its depth and thickness; and it might maintain its equilibrium in this state for a very long period indeed. But obviously such expansion could not last forever. Eventually some irregularity, either in the structure or in the expansion, or in both, would suddenly destroy its balance; the disruption of the ring would quickly ensue, and (owing to the superior strength of its own molecular connexions) its substance would aggregate into a sphere in some point of its circumference.

The ring's connexion with the original sphere, which had been continually fabricated and supplied as the separation of the two bodies proceeded, would follow the fractured portions of the ring, and finally, upon the spherical formation of the latter, would aggregate into a cylindrical bond between the newborn planet and its parent.

98. *Corroborative Evidences.*

(*a*) *Of Initial Solidification at the Surface.*—Let us here pause for a moment. Some readers may, perhaps, smile at the novelty of these ideas; and a few may be emphatically incredulous. But what particular idea in the few foregoing articles is it that can be regarded as really unworthy our credence? Apparently, it can not be the equatorial flow of the denser molecules, for that seems undeniable on the ground of terrestrial analogies. It is well known that when bodies of different densities are mechanically mixed in an enclosed space and then caused to rotate with a speed sufficient to overcome gravity, their parts having liberty of motion, the denser will always move towards the circumference. It is true that, if the attraction of gravity were supposed to operate upon the newly formed molecules, in accordance with the law of inverse squares, their equatorial flow would not then be indisputable: although, indeed, it may be remarked, as illustrating the confusion to which the assumption of such an attraction leads, that the most eminent physicists are by no means agreed as to where solidification really would begin. While some (among whom are Sir William Thomson, Prof. G. H. Darwin, Newcomb, Hopkins and Mallet) hold that it would begin at the center, others (among whom are Liebnitz, Descartes, Delaunay, Hennesly, Scrope, Babbage and Airy) hold that it would begin at the surface; and the question still remains unsettled.

In a work by T. M. Reade, entitled "The Origin of Mountain Ranges," in which he attacks the theory of central solidification, the following quotation is given (p. 126, Note) from Captain Dutton, of the United States Geological Survey:

> "The line of argument which is relied upon to sustain a cooling globe proves, when pushed to its consequences, that the great interior of the Earth has not, as yet, undergone any sensible amount of cooling. The only cooling which that argument admits of has been located in a thin external shell. * * * In short, the cooling would be only skin deep, while the nucleus is as hot as ever."

Mr. Herbert Spencer also shows* the rational superiority of the view that liquefaction and solidification would first take place upon the Sun's surface, while its internal regions would be still gaseous. M. Folie pointed out before the Paris Academy of Sciences (January 3, 1887) that the astronomical considerations which led Sir William Thomson and others to the belief that the Earth was centrally solid, proves, on the contrary, beyond doubt, the fluid state of the interior of the globe surrounded by a relatively thin outer crust. And an editorial in *Nature*,† speaking of the "supposition made by Sir W. Thomson as to the way in which the Earth cooled," says: "There have been people bold enough to think that in making this supposition, a great master of physics for once lent his name to an hypothesis which is in itself, physically, not very probable." Yet, of course, the attraction of gravitation is premised by these scientists, while in the present work that attraction would be profoundly modified (diminished) by other circumstances, as will be explained more fully farther on.

A fact which seems to be a general principle of matter, and which furnishes a valuable corroboration of the position here taken is that, even when subject to gravity, matter in the solid form, such as ice, type-metal, iron, glass, melted rock and earth, etc., will float

*In the *Westminister Review* for July, 1858; also *Recent Discussions in Science*, p. 297.

†Vol. XXXV, p. 361.

upon the same matter in a liquid or molten state.* In any case, therefore, it is hardly to be doubted that solidification from processes akin to cooling would begin on the surface of a globe and gradually extend downwards.

(*b*) *Of Ultimate Crust Rigidity.*—The ultimate rigidity of the crust can hardly be a ground for incredulity for the reason that we can not assign any proximate limit to the molecular development, and because, if the ultimate rigidity be denied, no conceivable cause can be assigned for the projection of the ring from the contracting spheroid (see Art. 70).

(*c*) *Of the Equatorial Crust Expansion.*—It may be thought that the circumferential expansion of the solid ring away from the sphere's center is a doubtful assumption; but it should be borne in mind that this expansion is supposed to take place very slowly and gradually, requiring, especially at first, a vast period to produce scarcely a measurable effect. However small the centrifugal strain upon the ring, as it is not supposed to be counteracted by a central attraction of gravity, and falling upon its connexion with the sphere, some yielding of that connexion would take place, which would certainly have a tendency to expand the ring. Even though the strength of the ring-connexion be quite sufficient at first to withstand the centrifugal strain, another consideration suggests that the strain would gradually become more and more powerful, and, falling upon the ring-connexion, *must* cause it to elongate. This consideration is that the ring and the parent spheroid would probably continue to rotate at about the same rate of angular velocity. The parent spheroid, being continually contracting its volume, owing to continual

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*[*] *Nature*, XVI, 23; *Amer. Jour. Sci.* III, viii, 287; *Nature*, XXVI, 138; Scrope, *Volcanoes*, pp. 84, 487; *Chemical News*, XVIII, 191.

surface development, would thus continually but gradually increase its angular velocity. A portion of this increase of angular velocity would be transmitted by the intervening connexion to the ring, and the absolute velocity of the latter would thus be increased at the obvious expense of the absolute velocity of the spheriod. It is quite possible that this increase of angular velocity of the spheroid would take place contemporaneously with a diminution of its absolute velocity. The absolute velocity of the ring would thus continually increase; and the consequent centrifugal tension upon it, tranferred gradually through its molecular connexions to the ring-connexion, would eventually become so great that that must yield and elongate. However, it is undeniable on other grounds that however rigid a ring of such vast diameter may be, the strain, if long continued, would not be without an effect. Prof. Tyndall has shown us (" Forms of Water ") that vast rivers of solid ice actually flow in their beds or channels. He has measured the motion of the Mer de Glace glacier and found it to be quite similar to that of water, only much more slow. And there is no end of evidence transmitted down from the great Ice Age proving the tremendous power of glaciers in grinding and polishing the rocky sides of the valleys through which they flowed, and in piling up the vast moraines or heaps of detritus which they deposited where they terminated in the ocean. The influence that causes the ice to flow is supposed to be that of the attraction of gravity, exerted upon the ice in an almost level bed. The power of the strain which causes it thus to move nearly horizontally may be very small indeed; but it is unvarying and long-continued and eventually produces very perceptible effects. Yet ice is, in a degree, rigid. It is not so rigid as some other substances; but all forms of matter appear to be rigid only in a degree, and not absolutely so. Glass is more rigid than ice, and steel is more rigid than glass. But even steel is far from being perfectly rigid. Sir William Thomson, states [*] that if the Earth were as rigid as steel, the amount of its yielding to tidal action would be about one-third of the tidal effect upon a yielding globe. In other words, if the Earth were a globe of solid steel, the effect of the Moon's attraction upon it would be to raise a tide about twenty-seven inches in height. These views are almost generally concurred in by other scientists. Prof. J. W. Judd[†] joins in the belief of Scrope and Darwin, that the solid rock masses of the globe under certain conditions actually *flowed* like viscous lavas; and mentions that this belief is fully corroborated by the experiments of MM. Tresca and Daubree. And if further evidence be required, we have it in the actual equatorial expansion of the Earth itself, in precisely the same manner as the planetary ring has been supposed to expand outwards from the solar spheroid. The Earth's equatorial regions have already expanded outwards from the center to a distance of 13 miles on every side; and the cause which everybody assigns for this extension, is nothing else than the Earth's rotation, even although it is supposed at the same time, that the centrifugal tendency generated by this rotation, is directly opposed by the vastly more powerful terrestrial attraction. Therefore, if the Earth's rotation, subject to such powerful opposition, is supposed to have projected the equatorial regions away from the center to a distance of 13

[*] *Phil. Trans.* 1863, p. 574; *Trans. Geol. Soc. Glasgow*, VI. 48-9.

[†] Address to the Geological Society, London, Feb. 18, 1887.

miles, it will hardly be denied that the rotation of the solar spheroid, with scarcely any opposition at all, is quite capable of projecting the solar ring outwards from its parent into complete isolation and eventual disruption.

(*d*) *Of the Connective Bond.*—With regard to the assumption of molecular connexions, and especially that the molecular connexions may be elongated by addition of atoms or molecules into planetary connexions, it seems, so far, to involve nothing unreasonable. It is everywhere admitted, that *some* connection exists between every portion of matter by means of which actions and interactions are supposed to take place. Usually such connection is designated a *force;* but as already stated, the very propounders of that force have have been ultimately driven to the belief that the true explanation of it will be found to involve some such material mechanism as is here assumed.

The inchoate planet is held by its molecular connexions upon the bosom of the parent sphere. When the increasing rigidity of the former and the continual development and contraction of the latter, necessitates a separation of the bodies, is it not reasonable that these molecular connexions, being thus subjected to a gradual strain, would be elongated conformably to it? and, as the tension becomes great, that it would draw either upon the connexions of the surface molecules of the sphere, or upon these molecules themselves, or upon both, to relieve the strain by additions to the connexion? Indeed nothing seems more reasonable. As already stated the connexions of developed molecules would be stronger than those of atoms or undeveloped molecules; the connexion subtending between the developed crust and the contracting spheroid would be stronger than the interconnexions of the comparatively undeveloped molecules of the spheroid's surface; and these last would in turn be stronger than the subjacent atomic connexions. The tension falling slowly upon the surface molecules would not cause their connexions to sunder because there are weaker connexions beneath them. Yet they would absorb a portion of the strain, the remainder falling upon adjacent molecules still less developed, or perhaps, down even upon the primary components. Thus is the tension distributed, and evidently the more it is distributed the less likely is any disjunction to take place. The tension falling upon the surface molecules and their connexions would slowly absorb some of them into the strained connexion, where they would themselves become strained into a new form. These would be followed by others and still others, and thus would a main connexion be formed between the planet-ring and the spheroid. As the ring becomes farther and farther removed from the latter, owing to the causes already assigned, it seems probable also that connexions would be formed between adjacent portions of the ring itself, which would also suffer stress by the continual ring-expansion. In the final disruption of the ring these would accelerate the approach of the disjoined parts to one point. At the same time the central connexion would follow the falling parts, and when these parts finally join in forming the spherical planet, the corresponding portions of the connexion would naturally coalesce into cylindrical conformity. In all this there appears nothing unreasonable or improbable; indeed, from approximate terrestrial analogies, it seems highly probable and likely to have taken place.

99. *Comparison of the Old and the New Ideas.*—If we contrast these views with the current ideas we may

see them in a still more favorable light. For, according to these ideas, an *increase of absolute tangential velocity* of the axial rotation of the spheroid is necessary to the projection of the ring; yet no such increase of velocity before or during the ring-period is rationally assignable (see Arts. 70 and 74). And after the ring is precipitated into the planet-sphere it is supposed to be held to the original spheroid by means of some *immaterial thing* admittedly unaccountable in its nature, in its origin, and in its operation. Even then it became necessary to introduce some *substance* into the interplanetary regions, and so it was imagined that these regions were filled with a highly volatile fluid called ether. But by what means this ether came to occupy or abide in these spaces still remains inexplicable. This is the present theory, and it does seem that, if we cast aside all bias, the comparison of the two theories is, so far, not at all unfavorable to the new one.

100. *Results of the Ring Disruption.*

(*a*) *Loss of Acquired Development.*—In the precipitation of the planetary ring into the spherical form, there are several things which require careful consideration. The first of these which we shall notice is that, in general, all the development of the ring would be lost in its collapse, so that the resulting planet would be in the same state of vapor as the original spheroid. We are impelled to this conclusion by the consideration that, if a very little development was preserved by each newborn planet more than was possessed by its parental sphere at *its* birth, then, obviously, in a vast number of generations, the structure of a new-born planet would be highly developed, and as the original spheroid of our system may itself have been the descendant of many preceding generations, and as that spheroid is supposed in the premises to be in a state of extremely rare and nearly homogeneous vapor, it appears that no other conclusion is admissible. Moreover, the conclusion is far from being improbable. The vast mass of solid matter in the ring, and the vast distances through which the greater portions of this mass would fall, must engender an amount of heat quite sufficient, in accordance with the estimates of prominent physicists, to reduce the colliding masses to their primordial state.

(*b*) *Axial Rotation of the Planet.*—A second result to be considered, which arises from the precipitation of the ring, is the axial rotation of the resulting planet. In the premises has been accorded to the original spheroid of our system some axial rotation, and it is obvious that this rotation would be imparted to the ring at the time of its gradual separation from the spheroid, and, after its disruption, changed into the planet's orbital motion.

Now, in the ring-collapse, one portion of the ring would move *with* this original motion, and the other portion would move *against* it, towards the point of aggregation. The portion moving *with* the original rotation would therefore have a greater absolute velocity around the spheroid than the others. This greater velocity, owing to the increased centrifugal tendency which it generates, would cause this portion to move farther outwards from the spheroid than the other, so that while the one part would approach the central point of aggregation upon the *outside* of that point, the other, owing to diminished absolute velocity, and consequently diminished centrifugal tendency, would approach it from the opposite direction upon the *inside*, the obvious result of which would be an axial rotation of the planet in the same general direction as the rotation of the original spheroid.

(c) *Recession of the Panet.*—It seems probable that, the *falling* velocity of both parts of the ring, especially when near the point of aggregation, would be much greater than the velocity of the original rotation; in which case the planet would be bodily carried outwards to a considerably greater distance from the center of the spheroid than that of the ring just prior to its disruption. The connexion of the planet being highly elastic and capable of adding to its length, as already indicated, would permit such removal, but would also slowly hinder it, and finally overcome it. This subject will be further alluded to in the next section of this article.

(d) *Cause of the Different Absolute Velocities of the Planet's Orbital Motion and of the Rotation of the Spheroid.*—This seems to be a fitting place for inquiring into the causes of the difference between the absolute orbital velocity of the planet and the absolute equatorial velocity of rotation of the spheroid. In other words, how is it that the absolute orbital velocity of Neptune is about three miles per second, while the absolute rotational velocity of the Sun's equator, even now, after the repeated accelerations which, as we shall shortly see, would take place in the several ring precipitations which have taken place since Neptune's time, is only a little more than one mile per second? and this when it is taught by the new theory that it is the rotational velocity of the Sun from which Neptune's orbital velocity has been derived. In answering this question, the first thing to be noticed is that the planet-ring, just at the point of separation from the Sun, would probably have the same angular rate of rotation as the other portions of the Sun, owing to the friction of the crust with the internal solar substance; and, being a broad, flat body, this would involve a much greater absolute velocity of the ring than of the equatorial surface, which it leaves behind. A second thing to be noticed is that the connexion of the ring with the Sun, being grosser in its earlier stage, would tend to maintain the same angular rate of the ring and the Sun for a considerable time after the separation. What absolute velocity the ring would gain by this means would obviously be lost by the Sun; and thus would the absolute velocity of the ring, compared with that of the Sun, be doubly increased, the increased velocity of the ring being, of course, transmittted to the subsequent planet.

In this greater absolute velocity of the ring we have a further cause of the recession of the planet; for the centrifugal tendency which the ring possessed just prior to its disruption would be greater than the elasticity of the connective bond could withstand after the spherical aggregation of the ring. Before the breaking up of the ring, the cohesive strength of the ring-substance would withstand a considerable portion of the centrifugal strain. After this cohesive strength was destroyed, the entire strain would fall upon the newly-formed planetary bond, which consequently would very probably yield, permitting the planet to move outwards until the centrifugal strain and the elasticity of the connexion were balanced.

(*e*) *Increased Axial Rotation of the Sun.*—Another thing to be noticed in the ring-disruption, is an increased axial rotation of the Sun. For, as already stated, one part of the ring has a much greater absolute velocity with respect to the Sun's center than the other. Owing to this greater velocity, its connexion would be in greater tension, and this tension would be transmitted to the surface molecules of the Sun; pulling them in the direction in which that portion of the ring was moving. Since the opposite portion of the ring has a smaller absolute velocity, the strain of its connexion upon the Sun's surface would be correspondingly weak; and so would not balance the greater strain upon the other side. And the obvious consequence would be an increase of the Sun's absolute rotatory velocity.

Here, then, is a very simple explanation of a phenomenon hitherto inexplicable. We now find a cause for the greater absolute velocity of the inner planets as compared with the outer, which the theory of gravitation is incapable of furnishing. For the force of gravity is supposed to act with precisely equal strength whether it acts upon another body or not. One body is supposed to attract another directly as its mass, and inversely as the square of the distance between them. It is true that, in conformity with this theory, the receding portion of the ring would attract the Sun; but its *recession*, instead of increasing the strain upon the Sun's surface, would diminish it. While, upon the other side of the Sun, the slow moving portion would be the nearer, and so its attraction or strain upon that side would be the greater. Thus in accordance with the theory of gravitation, if any variation whatever of the Sun's rotation would take place, it would be in the direction of *retarding*, rather than accelerating, that rotation.

(*f*) *Origin of Comets, Meteorites, Etc.*—Yet another thing to be noticed in the disruption of the ring, is the origin of comets, planetoids, and meteorites. In the light of the new theory, the comets and meteorites are nothing else than fragments of the planet-ring, which by some irregularity in the tremendous crash, are hurled outwards with such violence as to break the connexions, both with the Sun and the new-born planet; whence they will wander through space until their career has been arrested by collision with some other sun or planet. This together with the various peculiarities of comets, will be more fully discussed further on.

101. *Genesis of a Second Planet.*—The surface of the Sun would still continue to contract in volume and to develop in structure as before, with the exception of the single circumstance of being subject to the influence of the planet's connexion. The effect of this circumstance, however, would probably be nothing more in this respect than slightly to hasten the equatorial movement of the developed molecules. The same progressive steps as before would ensue, the same structural development, the same ring-formation with its evolving connexion, the same polar fractures and equatorial expansion of the ring, the same eventual disruption generating the new axial rotation and again increasing that of the Sun. And thus, as a result of almost an eternity of evolution, comes the final dissolution; and out of the dissolution arises a second new-born planet, with perhaps a comet or two and a shoal of meteorites. As the second planet-ring became separated from the Sun, different parts of it would be temporarily in the connexion of the first planet, serving, for the time, as a part of that connexion; and the two connexions mingling together between the ring and the Sun. In the collapse of the ring, its own connexion would follow it to the point of aggregation; the connexion of the first planet joining behind the falling portions of the ring, and so remaining intact.

102. *Genesis of a Secondary Connexion.*— But the connexion of the first planet would not *all* stay behind the precipitating ring. A part of it, it is reasonable to

suppose, would adhere to the ring-substance and would form a connexion between the two planets. This secondary connexion quite probably would differ materially from the primary connexion with the Sun in being more refined and rarer, agreeable to the functions it—or rather the remainder of the connexion—is required to perform. In support of this difference in the nature of the two connexions, it may be urged in the first place that the Sun, being by far the greater mass, would naturally claim the greater share of the first planet's connexion; whence the share falling to the second planet would be comparatively attenuated. And in the second place, those portions of the connexion which perform the office of holding the first planet in its orbit, and transmitting to it heat and light, may reasonably be supposed to be sufficiently fixed in that office to resist removal; so that the less necessary, or the unnecessary (that is, the less gross, or more volatile), portion only of the first connexion would fall to the second planet.

103. *Mutual Planetary Accelerations and Retardations.*—Owing partly to the increase of the Sun's axial rotation in the breaking up of the first ring, the orbital periods of the two planets would differ; that of the inner being the shorter. The inner planet would, therefore, move away from the first planet between conjunction and opposition, and would approach it between opposition and conjunction. The interplanetary connexion would therefore be subjected to a long-continued tension; the substance for its elongation being supplied from the atmospheres of both planets. Evidently when the connexion between the two planets is thus strained, the outer planet would be accelerated, and the inner planet retarded. But after opposition, the

reverse would occur; for whatever resistance was offered by the atmospheric molecules in elongating the connexion may be supposed to be compensated by their mutual affinity when the tension is removed. So that the acceleration and the retardation of each planet would be approximately equal.

104. *Systemic Complexity.*—Each planet being at its birth a globe of vapor, similar in all respects except magnitude to the original solar spheroid, would contract its volume by surface development and pass through the same generative stages as the parent; the eventual result of which would be the birth of satellites in the same manner as the planets. The satellites would be connected primarily with the planets and secondarily with the Sun; and the action of the secondary connexions upon the satellites would be similar to, though somewhat less in magnitude, than their action in the case of the planets.

It seems unnecessary in this place to follow the details of the genesis of each of the other planets and satellites. The generating process of each planet is but a repetition of the steps involved in the generation of its predecessors, with the exception of an increasing complexity of interplanetary connexions, as every succeeding planet would be connected with every preceding one. This complexity becomes mazelike, even if there were no greater number of connected bodies than is comprised in the Solar System at its present stage. But if we consider that our Sun is but a planet of a still greater system, having its own proper connexions with its sun and its sister planets—nay, when we consider, as according to the new theory we must, that our Sun is but a satellite—a satellite of the tenth or twelfth order of descent from a grand but vastly remote parent; when we consider the vast number of other suns, planets, and satellites necessarialy involved between us and that parent, with each of which our own little world is quite probably connected—truly the highly intricate plexus of connexions thus approximately indicated is apparently not very far removed from the old universal ether after all. But there is this difference: there is a *system* in the former, while the latter is a mere chaotic homogeneity; an important distinction, and perhaps leading to important results.

It would be equally impossible and unnecessary for us to trace out all the connexions involved in our system and their various effects upon each other, and upon the bodies they connect. It seems that if the moving equilibrium of any three bodies can be demonstrated to be stable upon this connective theory, that of a greater number need not perhaps be considered. For the addition of a fourth, or a fifth, or any number of other bodies *in a regular manner*, while increasing the complexity, apparently involves no new or greater difficulty than is found in the simple system of three bodies. The grand Complexity seems to be but a repetition and combination of simple unities compounded and recompounded in time, in space, and in motion.

When a planet, or a satellite would infringe upon some other connexion than its own, the latter would part its molecular attachments and fix them upon the entering body. During the passage, the latter would practically form a part of the connexion; and when the body would pass out of it, the molecules of the connexion, following its contour and successively attaching themselves to the different portions, would finally close up behind it and unite together as before. The connexion of the one body would pass through that of the other much upon the same principle except that of the lateral molecular connexions of both planetary bonds, instead of the longitudinal molecular connexions of one only, would part, those of each to admit the longitudinal connexions of the other; these lateral connexions joining together after the passage in the same manner as the longitudinal connexions during the passage through them of a heavenly body.

CHAPTER II.

EVOLUTION OF THE SIDEREAL SYSTEM.

105. *The Original Sidereal Spheroid.*—If the solar spheroid with which we started, instead of being regarded as the parent of the Solar System, were considered as the parent of the Sidereal System, still the same premises would apply, and the same results of the process of subdivision or segregation, would evidently be arrived at. Planet after planet would be continually given out from the spheroid in the equatorial plane of its rotation, its still remaining nucleus constituting the center around which all these bodies revolve. Each of these grander planets would in their turn give forth sub-planets and constitute a sub-system of which the still remaining nucleus of the planet would be the immediate governing center. Each sub-planet in turn would sub-divide in a similar manner, the sub-divisions of which would also become the centers of a still inferior order. And so on down to the present stage. In corroboration of this, we observe that the bodies of the Sidereal Systen are distributed principally in one plane, that of the Milky Way, which would thus be

determined as the equatorial plane of the Sidereal System; this, it may be added, being also quite in accordance with the views of nearly all eminent philosophers and astronomers. And in still further corroboration, we observe that the greatest degree of subdivision, as manifested in the nebulæ, has taken place in the peripheral parts of the Sideral System, in the older subsystems just where we should reasonably look for it.

106. *The Sidereal System and What It Includes.*—It has been thought probable by many astronomers that the nebulæ are other galaxies, or sidereal systems, at distances proportionately as great from ours as the distances of the fixed stars are greater than the planetary distances. And they were not unnaturally led to this view; for, gazing at these nebulæ, they looked through and beyond the countless stars of the Milky Way, and they saw nothing beyond them but the perfect blackness of the heavens. But the nebulæ, though probably beyond the visible stars of our galaxy, can hardly be at such almost infinite distances beyond them as has been supposed. For if the distance of the nebulæ from the Sidereal System were about a million times that of the fixed stars from us, as the above supposition implies, it would inevitably follow that the telescopic power required to resolve these remote galaxies into stars must be incomparably greater than that required to resolve our own galaxy into stars. But this is not the case, as it is well-known that the same telescopic power by which many of the stars certainly belonging to our own galaxy are barely visible, will clearly resolve many of the nebulæ into distinct and separate stars. And it seems far more reasonable to suppose that the stars of our own galaxy and the starlets of the nebulæ, both of which are barely

discernible separately in the most powerful telescopes, are both about the same distance from us, than to suppose that the starlets of the nebulæ are each a million times greater in volume than the stars of the Sidereal System.

It is not here contended that there are no other galaxies or firmaments beyond our own, but only that if such really exist, they must be invisible to us, owing to the remoteness of our relationship to them and to their immense distance from us. From the present state of our knowledge it seems nothing less than presumption either to assert the existence of other firmaments than ours, or to deny that our firmament may even be a constituent atom of an eye beholding but a tittle of the Cosmos.

107. *Arrangement of the Sidereal System.*—According to the telescopic researches of Sir William Herschel, our little world is situated nearly in the plane of the Galactic Circle which passes through the Milky Way, but somewhat eccentrically, being apparently nearer to the southern than to the northern portion of that circle. In, or very nearly in, this plane, which differs only about 40° from that of the Solar System, the vast majority of the heavenly bodies lies; and, as we recede from it, the number of stars in equal areas of the sky rapidly diminishes up to the Galactic Poles. Had the evolution of every successive body of the Sidereal System been regular, all the stars and planets, according to the new theory, would lie in this plane. But as the evolution of the bodies in the Solar System has not all been regular, the motions of some of them being at very great inclinations to the plane of the Sun's equator, it might reasonably be expected that the same irregularities would occur in the Sidereal System in

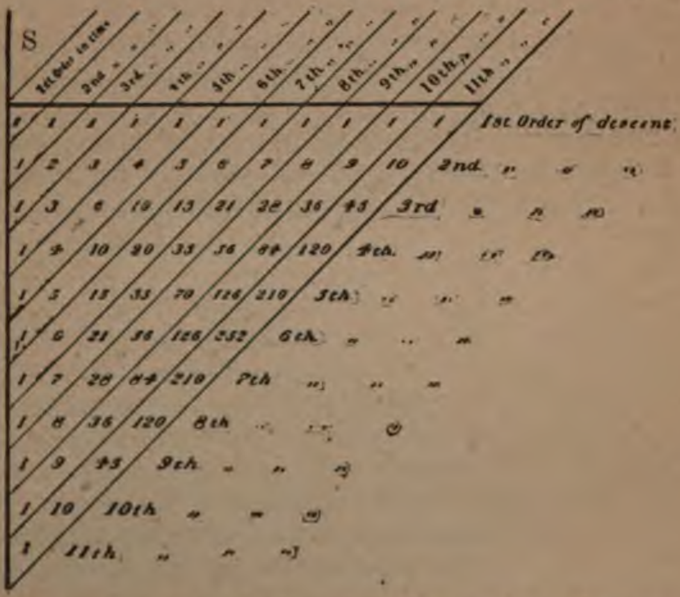
the same proportion. The stars which we observe in high galactic latitudes furnish therefore no greater objection to the common origin of all the bodies of our firmament than the great inclinations of the orbit planes of the satellites of Neptune and Uranus furnish to the common origin of all the bodies of the Solar System.

108. *Dark Bodies of the Sidereal System.*—It may be incidentally remarked that, although apparently numberless, the visible bodies of our firmament are in all probability few compared with the numbers of those, equally large, which are totally invisible to us. Beyond the puny limits of our own Solar System, we observe, even with the most powerful telescopes, probably none but incandescent bodies shining by their own proper light. Around many of them and receiving their light and heat, are revolving other bodies which of themselves give forth no light, just as we find the dark planets circling our own Sun. Occasionally, indeed, we observe planets revolving round their primaries, as in the cases of periodic, binary, and multiple stars (of which more farther on); but those planets themselves are theoretically of recent origin and in an incandescent state. As not more than two or three such may reasonably be supposed to exist among the many dark bodies of the Solar System, we may safely presume that in similiar systems a similar state of things prevails. And even in the systems in which the incandescent planets are observed, it is quite probable that they are not always unaccompanied by more developed sister planets.

109. *Probable number of the Heavenly Bodies, and of Their Successive Generations.*—To gain some idea of the number of successive generations of heavenly

bodies which would have taken place from the original spheroid of the Sidereal System down to the present time, let us assume that heavenly bodies of all magnitudes are equally prolific; *i. e.*, that suns, planets, satellites, etc., have in the average (to use a familiar phrase) the same period of gestation. The actual number of stars visible to the naked eye, including all down to the 7th magnitude, is about 6,000; and the number telescopically visible down to the 13th magnitude is about 43,000,000. Let us put the whole number of heavenly bodies, from those of the first magnitude down to those which are barely visible in the most powerful telescopes, both inclusive, at one billion; and let us further suppose that the number of dark bodies in the Sidereal System which are wholly invisible to us, is about ten times as great as the number we observe; and finally to the sum thus obtained, let us add for accidental contingencies, enough to make one hundred billions, and call this the number of bodies regularly derived, (excluding meteorites and most comets, which are not supposed to generate new bodies) of which the Sidereal System now consists. From these various facts and assumptions it follows that the number of generations from the primordial spheroid of the Sidereal System down to the present time, is only about thirty-three; a generation in this case being the time elapsing between the birth of a heavenly body and the birth of the next heavenly body from the same parent. In the following table, let S represent the primordial spheroid of the Sidereal System, and let the horizontal columns represent the orders of descent of the heavenly bodies and the diagonal columns, the orders of their generations in time; then the figures in these columns will denote the number of bodies of each order of descent, in each order of time down to the 12th.

In the first order of time, the spheroid would give birth to one body of the first order of descent. In the second order of time, the latter would give birth to one body of the second order of descent, and the spheroid would give birth to another body of the first order of descent. In the third order of time, there would be one body of the first order of descent from the spheroid, two bodies of the second order of descent from the two



1	1	1	1	1	1	1	1	1	1	1	1st Order of descent.
1	2	3	4	5	6	7	8	9	10	2nd " " "	
1	3	6	10	15	21	28	36	45	3rd " " "		
1	4	10	20	35	56	84	120	4th " " "			
1	5	15	35	70	126	210	5th " " "				
1	6	21	56	126	252	6th " " "					
1	7	28	84	210	7th " " "						
1	8	36	120	8th " " "							
1	9	45	9th " " "								
1	10	10th " " "									
1	11th " " "										

previously existing bodies of the first order of descent, and one body of the third order of descent from the previously existing body of the second order of descent. And so on; the number of the bodies of the various orders of descent, in any order of time, forming the co-efficients of the terms of a simple algebraic binomial, raised to a power denoted by the number less one of that order. Thus the number of the bodies of the various orders of descent, from the first to the seventh inclusive, in the seventh order of time, are 1, 6, 15, 20, 15, 6, 1, respectively; these numbers being also the co-efficients of the respective terms of $(a + b)^6$ fully expanded. We also observe that the number of bodies of all orders of descent, in any order of time, is just twice the number in the preceding order of time; so that the sums of all new bodies in each successive order of time, form the terms of a geometrical progression of which the ratio is 2. And finding the sum of 33 terms of such a series, the first term being one, we have a number larger nearly by half than the number of bodies of which we assumed the Sidereal System to consist.

It would follow from this consideration, then, that the Sidereal System is composed of some thirty-two or three consecutive systems; and also that the Solar System, if its original spheroid was regularly derived from the primordial spheroid of the Sidereal System, (as seems very probable in comparison with the supposition of its being a comet), and supposing Neptune to be its first planet, and the Asteroids temporally equivalent to another planet—would probably, from its nearly central position, be a member of the tenth of these consecutive systems from the sidereal center. This, however, is only a first approximation. Several of the assumptions on which it is based may be wide of the actual facts.

110. *The Origin of Motion.*—Of course axial rotation and orbital revolution, if premised in the original system, would obviously, according to this theory, be characteristic of each successive system, from the first down. But the origin of rotation in the primordial system of the entire Cosmos is, to say the least, very *difficult* to conceive; not indeed for the want of a

cause of rotation, but for the want of a means of radiating away the surface heat of the spheroid, supposing it to be the primordial one of the whole universe, and its surface constituting the utmost bounds of all matter. If such a means of radiation be assumed or conceded, then contraction of the spheroid would follow; which, in the absence of rotation, would result eventually in a hollow shell, instead of the equatorial ring resulting from rotation. In the eventual collapse of this shell, it is reasonable that some irregularity of its structure would determine a preponderance of momentum of a portion at least in some particular direction; in which direction that portion would be constrained to rotate, owing to the causes already assigned. [See Art. 100 (*e*).]

CHAPTER III.

COSMICAL GRAVITATION.

111. *The Ball-and-Spring Hypothesis.*—After this rapid general survey of cosmical and systemic evolution, we may now proceed to the consideration of that evolution more in detail, and observe what corroborative or contradictory evidence the new theory meets with in the various phenomena involved.

Of the first importance in this direction is the phenomena of cosmical gravitation and a comparison of the action of the planetary connexions in producing these phenomena with that of the force of gravity. The theory of gravitation is by no means a flimsy one which may be lightly considered and passed over. The attraction by means of which bodies fall to the Earth's surface, when extended outwards to the Moon in accordance with the law of inverse squares, almost exactly accounts for the fall of that body towards the Earth in each second of time. If the Earth's surface attraction be extended outwards to the Sun in the same manner and then compared with that of the Sun upon the Earth, it is found that the effect of the latter is some 328,000 times more powerful than the former. And when this value of the Sun's attraction is similarly extended from the Sun outwards to each planet of the Solar System successively, it is found to account for the fall of these bodies in each second with the same exactness that the Earth's attraction accounts for that of the Moon. Here is a basis for the theory of gravitation, the apparent solidity and strength of which seems to be completely impregnable; and truly it is not to be wondered at that the intellect of a Newton should place great reliance upon it. But that he did not place as great reliance upon it as some of his recent disciples do, sufficiently appears from the fact that he regarded it as the greatest of absurdities to imagine "that one body might act upon another through a vacuum without the mediation of anything else by and through which their action and force may be conveyed from one to another." And Sir William Thomson says that we must be temporarily satisfied to explain capillary attraction as intensified Newtonian attraction "until we see how gravity itself is to be explained as Newton and Faraday thought it must be explained, by some continuous action of intervening or surrounding matter."* It is this continuous action of surrounding and all-pervading matter which constitutes the essential feature of the new theory we are now considering; and the wider operations of which we are now to examine more closely.

**Nature*, XXXIV, 271.

But how can the phenomena, which so strongly corroborate the theory of gravitation, be accounted for on the basis of the material connexions which the new theory postulates? How can this material medium explain the fact that the fall per second of every body, belonging to any particular system, is related to that of any other body of the same system in the precise ratio of their square distance reciprocals? that, in fact, in any particular system, the fall per second of each of its members towards the center of motion, may be regarded as a uniform function of the distance from the center? Yet, strange as it may at a first glance appear, the material cord which, according to the connective theory, joins the planet to its primary and causes the former to fall towards the latter, involves exactly the same distance-function of that fall that is involved in the theory of gravitation.

"*What* there is between the sun and the planets that makes each of them pull the other, Newton did not know; nobody knows to this day, and all we are now able to assert positively is that the known motion of the planet is precisely what would be produced if it were fastened to the sun by an elastic string, having a certain law of elasticity. Now observe the nature of this discovery, the greatest in its consequences that has ever yet been made in physical science:—

"I. It begins with an hypothesis, by supposing that there is an analogy between the motion of a planet and the motion of a ball at the end of a string.

"II. Science becomes independent of the hypothesis, for we merely use it to investigate the properties of the motion, and do not trouble ourselves further about the cause of it."* May it not be, indeed, that science has become *too* independent of the hypothesis—that, in fact, it might be well for it to trouble itself with an earnest and humble inquiry into the real operation of this ball-and-string theory? The elastic string, by the new theory, is the primary connexion of the planet, and the law of its elasticity we may now proceed to investigate.

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* Prof. William Kingdon Clifford. Discourse at the Royal Institution, London. *Humboldt Library of Science*, vol. vi, p. 281.

112. *The Factors of Cosmical Gravitation.*—It may be regarded as axiomatic that the strength of the various primary connexions would vary with the different circumstances attending their evolution. It may be well to consider the most important of these, whether they may be found to affect the strength of the connexion or not. These circumstances are: (*a*), the rotational velocity of the primary body; (*b*), the structural development of the connexion, and (*c*), the density of the connective atmosphere upon the surface of the primary body.

(*a*) *Rotational Velocity of the Primary Body.*—This factor would have the least value in the case of the first planet of a system, and would gradually increase in value for each subsequent planet, as already shown (Art. 100, *e*). While the planet-ring was extending outwards from the primary body, and the primary connexion was forming between the two, the extra strain which the greater rotational velocity involves in the inner or more subsequent ring-formations would produce some effect, either upon the connexion or the ring itself. But here we must bear in mind that the ring is a solid body firmly held together by molecular attraction or cohesion. This cohesion would evidently be more powerful than the centrifugal tendency of the greater rotational velocity of the ring, at least until the planet was formed and the connexion matured.

In fact, the cohesive attraction and the centrifugal tendency would be directly opposed to one another; and it would seem that the former would receive the full brunt of the latter, so that the forming connexion would be left unaffected by this cause. The sole effect of this factor, therefore, would appear to be to hasten the expansion of the ring, and so diminish the generative planetary period. So that, so far as the rotational factor is concerned one planetary connexion would appear to differ in no respect from another.

(*b*) *The Structural Development of the Connexions.*—For the consideration of this factor, we may take the case of the Earth and the Moon. When the Earth was in the first stage of its planetary existence as a globe of fiery vapor, not only would its surface be vastly enlarged, in comparison with its present surface, but all its present surface development would be wanting. Nothing but the primordial vapor existed on its surface, and this in the full and fiercest energy of its molecular heat-motion. Can we, then, avoid the belief that the structural development of the surrounding connective atmosphere would correspond to that of the Earth's surface at that time? And does it not seem equally probable that, as the development of the Earth's surface advanced, the development of the connective atmosphere would advance correspondingly? According to this view, then, the Earth's connective atmosphere would increase in development as the Earth contracted.

This is not the proper place to show *how* the greater central development of the Earth's connective atmosphere would cause bodies to fall towards the center; it belongs to a more advanced stage of cosmical evolution. But, without showing the actual mechanism of that movement, it seems tolerably evident that a body possessing a certain degree of molecular development would be moved (by means of its secondary molecular connexions or connecting-rods with the molecules of the connective atmosphere) in that direction in which the atmospheric molecular motions were most in harmony with its own. Now, as the Earth contracts in volume subsequently to the formation of the Moon, and its surface development proceeds, the Moon's connexion must be elongated or spun out over the interval which the Earth has contracted; and, as the connective atmosphere itself undoubtedly furnishes the material for this elongation, it clearly follows that the connexion would be possessed of the same structural development at every successive stage as the Earth's connective atmosphere.

Here, then, is a circumstance that would modify a planetary connexion so as to enable it to act in a manner similar in a small degree to that prescribed by the law of inverse squares. But, on the other hand, it does not account for the distance variation of the planetary falls per second; for the reason that each planetary connexion would be an almost exact repetition of its predecessors in this respect. The primary body immediately after the birth of each successive planet would obviously be in the same state of surface development. About the same degree of development would beget the planetary ring in each case, and the ring would in every case appropriate the developed crust of the primary down to the same degree of development. So that after each ring-separation the remaining degree of development of the primary would be about the same. And so the crust development of the primary and the corresponding development of its connective atmosphere would be similar in kind and degree after the birth of each planet. Therefore, while this factor applies to an individual connexion, modifying it in time in accordance with the varying structural development to which it is subject, it does not apply to two connexions so that the one will differ in any degree from the other. Indeed, it may be objected, perhaps, that even in the case of a single connexion, the varying structural development of the primary crust would fail to produce a measurable change of the structural development of the connective atmosphere. For, subjected to the most intense process of destruction which man can produce, the function of the connective atmosphere now upon the Earth's surface, and which, according to these views, would now be highly developed, remains precisely the same as under ordinary circumstances. A body appears to weigh none the less when cast into the fiercest furnace, although the connective atmosphere surrounding it at that time is subjected to a very intense degree of heat.

But in answer to this objection it may be remarked that the puny furnaces of man are quite incomparable to the vast and grand catastrophes of nature. The greatest and fiercest conflagration possible with man would scarcely be a drop in the ocean of the Earth's connective atmosphere; so that the structural development of so minute a portion of it as would thus be affected by our fires might easily be sustained by that of the general atmosphere surrounding it; whose molecular motions we know are capable of being transmitted nearly 200,000 miles in a single second of time. If the entire surface of the Earth were simultaneously subjected to an intense degree of heat the effect of which would extend for thousands of miles beyond the surface, then we should have something comparable to the operations of nature; and which in all probability would diminish, in a degree, the weight of every body subjected to it. The nearest we can approach an instance, wherein the whole of a body's connective atmosphere would be affected, is by way of analogy. A magnet, if subjected to a certain degree of heat, loses its power of attraction in a degree; and even, if the heat be sufficiently intense, will lose that power wholly. Yet, without undertaking here to prove that the connective atmospheres of the magnet and of the Earth are exactly similar with respect to the mechanism of their function of attraction, it seems tolerably plain that the loss of that function in the heated magnet is due to the destruction of some such molecular arrangement or development, as, in the case of its larger analogue, the new theory implies.

But still the action of the planetary connexions as a whole exhibit no trace of conformity to the law of inverse distance squares upon which the theory of gravitation fundamentally rests. There is yet remaining, however, a circumstance which, as we shall now see, fully harmonizes the action of the connexions with that law.

(c) *The Density of the Connective Atmosphere upon the Surface of the Primary Body.*—Let us in imagination extend the volume of the Sun outwards again to its primordial limits, or nearly to Neptune's orbit. The Sun's surface would thus of course be vastly enlarged; and it is equally obvious that the density of the solar connective atmosphere upon that surface would diminish in the precise ratio that the surface increased. It is also an elementary geometrical truth that the surface of the Sun would vary in the direct *ratio* of the square of its distance from the Sun's center. From all of which it manifestly follows that the density of the connective atmosphere upon the Sun's surface varies inversely as the square of the distance from the Sun's center; or precisely in accordance with the distribution of the supposed force of gravity in the theory of gravitation.

Let us suppose now that the Sun has contracted in volume, that a developed crust has been formed, and that this crust is about to separate from the Sun to form the Neptune-ring. The inchoate planetary connexion would be evolved out of the Sun's connective atmosphere, which at that time possessed a certain degree of density; and it seems very evident that the density of the forming connexion would be similar to, or at least modified in conformity with, that of the connective atmosphere out of which it was spun. It seems unquestionable, from the view which we are now able to take, that the connexion would be evolved out of the connective atmosphere of the primary body. And since the centrifugal tendency of the ring's rotation affects the forming connexion to a merely infinitesimal degree, if at all, being primarily directed against the cohesive attraction of the ring itself and bringing about its eventual rupture—no conceivable reason seems assignable why the density of the connexion should be either greater or less than that of the material out of which it is formed. From which it clearly follows that the primary connexion of the planet Neptune, or so much of it as was formed up to the time of the rupture of the Neptune ring, would have a constitution precisely conformable in degree of density, strength, and elasticity to that of the connective atmosphere of the Sun in the period in which the ring existed. After the rupture of the ring, as the Sun contracted in volume, and as the density of its connective atmosphere consequently increased, the newly formed portions of the planetary connexion would partake of the increased density of that atmosphere, and would therefore be stronger than the portion of it that was first formed. But a connexion, in common with everything else, can not be stronger than its weakest part; so that, whether the planet moves outwards or inwards from the place of its ring-existence, the portion of its connexion formed in that place would for all subsequent ages determine the strength and elasticity of the entire connexion as such.

Let the Sun still further contract in volume, and let a second planet-ring project outwards from its surface. At this period the connective atmosphere upon the Sun would obviously be denser than in the period of Neptune in the ratio of the inverse squares of the Sun's radii at these periods, as already shown. The density of the connexion of the second planet would therefore be greater than that of the first connexion beyond the second planet in the same ratio that the surface density of the connective atmosphere was greater at the later time. And the greater strength and elasticity thus conferred upon the second connexion would regulate its action as a whole for future ages, just as in the case of the first connexion. Still further contraction of the Sun would beget a third ring and a density and consequent strength and elasticity of the connective atmosphere and therefore of the planetary connexion formed out of it, which would be greater than in the preceding periods in the same ratio as before. And so on, in the case of every subsequent planet-ring and planetary connexion in the Solar System.

Had we commenced with any other system, the reasoning would have been exactly the same. The Saturnian System was evolved in precisely the same manner, but more rapidly, owing to the greater rotational velocity of the original spheroid of that system. And the Terrestrial System was similarly evolved, only the comparative slowness of the Earth's rotation causes the generative period to be much greater. And similarly also, no doubt, in the cases of those systems which are superior to the Solar System, up even to the Sidereal System itself.

113. *Difference Between the Actions of Gravitation in the Two Theories.*—Here then, in the case of the attraction of gravitation, is the general law of inverse squares exemplified in the connective theory of cosmical evolution precisely the same as in the theory of gravitation. The restraining strength of a planetary connexion is seen to vary inversely with the square of the distance at which it acts, just the same as in the case of the supposed force of gravity. Where, then, it may be asked, is the difference between the restraining action of a connexion and the supposed force of the present theory? A moment's consideration will suffice to make this clear. For in the case of a primary connexion, *the restraining energy is constant*, whether the planet move outwards from, or inwards towards, its primary. The absolute velocity of a planet in its orbit would also be invariable (in the absence of external agencies, of course, and aside from mutual accelerations and retardations), for the reason that there is nothing conceivable to which any change of it is assignable (see Arts. 70 and 73); although its angular velocity, owing to various causes, may vary considerably. Therefore, since the restraining power of the connexion, and also the absolute velocity of the undisturbed planet are

constant, it is manifest that if the planet, owing to any ordinary disturbing cause, should move outwards beyond its normal distance, the centrifugal tendency would diminish, owing to the diminution of the planet's angular velocity involved in the outward movement. It is very plain, therefore, that the outward movement could not continue very long subject to a continually diminishing centrifugal tendency and a constant restraining power. And it is equally obvious that if the planet would move inwards to less than its normal distance, the centrifugal tendency would increase, owing to the increased angular velocity accompanying the inward movement; and that this inward movement could not long continue subject to a continually increasing centrifugal tendency and a constant restraining power.

By the connective theory, then it would be a physical impossibility for a planet to move beyond a limited range of its normal distance from its primary in consequence of the ordinary perturbations to which it is subject, such as the accelerations and retardations of the secondary connexions. But compare this now with the supposed force of gravity. As the planet would move outwards, the restraining force, instead of remaining constant upon it like the elasticity of the connexions, would continually diminish in power; so that, in order that the planet may not fly entirely away from the Sun, it becomes necessary to suppose that the absolute velocity of the planet becomes less as it moves outwards, and the centrifugal tendency thus diminished in just the same ratio as the supposed restraining force. Similarly as the planet moves inwards, the power of the supposed restraining force would increase *upon it*; so that, in order to prevent its falling upon the Sun, it becomes necessary to suppose that the planet's absolute velocity is increased, that the increased centrifugal tendency thus generated may balance the increased radial force. And this necessity of some means of thus maintaining the balance of the two opposing tendencies appears to be the sole justification for supposing that such a change of the planets absolute velocity would take place; as no other adequate means of maintaining that balance, in accordance with the theory of gravitation, is conceivable.

We thus see that even the very foundation stones of the theory of gravitation are readily, and even advantageously, replaceable by the material of the connective theory; and, if it be granted that the law of equal areas has no foundation in fact, as our investigations so far seem to prove, then the theory of gravitation has really no foundation at all, and it stands condemned by the very phenomena which have hitherto been regarded as furnishing its main support.

114. *Action of the Secondary Connexions.*—With respect to the action of the secondary connexions, such as those of the planets with one another and of the Sun with the satellites, its nature does not at the present stage of the inquiry appear to be determinable. These connexions would evidently differ from the primary connexions in their function and consequently in their materiality. As already indicated, the former would be more refined, and would therefore possess less strength. Consequently their action would be characterized by less energy and power. But what diminution of energy and power of action would be attributable to these causes does not seem to be ascertainable owing to the quantitative vagueness of the causes themselves. The secondary connexions would certainly produce

considerable effects upon the motions of the bodies between which they subtend. In fact their action would constitute the ordinary causes of planetary perturbations. In the case of two planets thus connected, the connexion would at certain times retard the orbital motion of one and accelerate that of the other, while, at other times, these actions would be reversed; thus causing the chief anomalies of planetary motions which we observe. Similarly in the case of the Moon, the secondary connexion of that body with the Sun would at times accelerate its motion round the Earth and at other times retard it; thus no doubt giving rise to the wider peculiarities which the lunar motion is observed to possess. The Moon's connexions with the other planets would also produce noticable effects upon its motion. But none of these effects appears to be exactly calculable at the present time. And in corroboration of this the most recent authorities on this subject are compelled to admit from their actual observation that the various pecularities of the lunar, and even of the planetary motions, are yet by no means all accounted for.

115. *Accurate Prediction of Astronomical Events.*—It may perhaps be wondered how such accurate predictions of astronomical events, such as eclipses, conjunctions, transits, etc., can be made in connection with such imperfect knowledge of the causes affecting the lunar and planetary orbits. But it is to be observed that such astronomical events are not predicted from our knowledge of these causes themselves, but from our knowledge of their effects as ascertained from actual observation. From our long-continued observations of the actual anomalies of the motions of the heavenly bodies, we are at length enabled to foretell *with a high* degree of accuracy the orbital positions of

any or all of these bodies at any particular time, providing it is not too remote. But this does not appear to involve any knowledge whatever of the real causes which produce these phenomena. The computation of future events seems to be grounded almost entirely upon the observations of similar events in the past; upon the observed effects of certain causes and conditions similar to those to which the future event is known to be subject; in fact upon a *practical* rather than upon a *theoretic* basis.

CHAPTER IV.

THE COSMICAL DISTRIBUTION OF HEAT AND LIGHT.

116. *The Connective Theory of Heat Distribution.*—By the popular theory, the Sun's heat and light is equally diffused outwards in all directions from that body; diminishing at any point in the same ratio that the square of its distance from the heat and light source increases. The confusion resulting from this view, regarding the actual temperature of the Sun, has been already noticed (Art. 84); and it is significant that this view makes the Sun to be much hotter than is found to be the case from actual observation.

Now the teaching of the new theory with respect to solar heat is, it may be said, almost the reverse of Newton's theory. Instead of the Sun's heat being diffused outwards from the Sun equally in all directions, it would be distributed from that body in a comparatively small number of lines or connexions; which being chiefly with bodies vastly smaller than the Sun, the heat instead of being *diffused* outwards to these bodies, would rather be *concentrated* upon them. But it is far from being contended here, that on this account the Sun's surface temperature is less than that we receive on our hottest summer day. We really do not know what the Sun's temperature is; and from the nature of the case, we can as yet hardly assign to it even a probable value. The unknown factors, which render the real value uncertain, are numerous and important; but it does not appear impossible that at some future day we may determine them all, and so ascertain the actual solar temperature.

In the first place, we have no apparent means of knowing what portion of the actual solar heat is imparted to the connective substance at the Sun's surface. In the second place, we can not say how the transmission through the connective substance affects the unknown portion thus imparted. In the third place, we are not certain of the effect of our own upper atmosphere upon the unknown portion transmitted to it. And there are still other unknown factors of minor importance. We can not reason here from analogy, because we have no analogue. We are surrounded on all sides by a connective atmosphere made up of an unknown number of individual connexions of an unknown number of kinds; and we can not yet separate with any certainty, the effect or influence of any one from the effect or influence of the others. Heat is a certain species of motion; but it is not certain whether some other species of motion, which is not heat, may or may not generate heat motion in certain substances or *vice versa*. By the new theory, heat is but a degree of an essential, if not indeed *the* essential, property of all matter; and we know not yet how many degrees are mutually convertible. We shall therefore leave the *discussion* of these questions for the present, until at least we see what light the examination of cosmical evolution in its future processes may cast upon them.

117. *Comparison of the Two Theories.*—The new theory places us apparently in no greater dilemma, in this respect, than we are now in, for the same difficulties (together with several others more important) are met with in the present theory also. Prof. Langley says: "If we had a thermometer so long that we could dip the bulb into the sun and read the degrees on the stem here, we should find out what observers would like very much to know, and at present are disposed to quarrel about. The difficulty is not in measuring the heat, but in telling what temperature corresponds to it, since there is no known rule by which to find one from the other." * Prof. Tait says: "The energy of vibrational radiations is a transformation of the heat of a hot body, and can be again frittered down into heat, but in the interval of its passage through space, devoid of tangible matter, or even while passing unabsorbed through tangible matter, it is not necessarily heat." Prof. W. K. Clifford states: "There is no reason why the vibratory motions of the ether should not be transformed into other kinds of ethereal motions." And many other physicists might be quoted to the same effect.

That heat in certain cases is transformed into other kinds of energy, is now a mere commonplace of the school-books. A very manifest instance of this transformation is that, in the powerful friction caused by boring iron, as in the making of cannon, the enormous amount of heat thus generated disappears at once, as such, when the iron operated upon is strongly magnetized. But whether or not similar transformations take place in our own atmosphere, in the solar atmosphere, in the region between the two, or in all three, is equally an unknown factor in either theory. But although these uncertainties are common to both theories, none of the more serious objections, which the present theory involves, are applicable to the new theory. We certainly would not infer from the latter, as is unavoidably inferable from the former, that the Sun's temperature would be several millions of degrees; that the temperature of the Earth ought to be much higher during our winter than during our summer, or that more solar heat would be received at the North Pole during our summer than would be received upon a point at at the Equator (see Arts. 84 to 86, inclusive).

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* *Century Magazine*, December, 1884.

With respect to this last inference, the old theory assumes that equal areas at right angles to the solar beams receive the same amount of sunheat, whether at the Pole or at the Equator; whereas, the new theory implies, on the contrary, that the amounts of sunheat which fall upon equal areas at right angles to the solar beams on different portions of the Earth's surface are not equal, *but vary directly about as the Earth-Masses directly behind such areas from the Sun;* because the density of the tension- or heat-rays of the solar connexion reasonably depends upon the *mass* rather than upon the *surface* to which it is distributed; and because the amount of solar radiation obviously would vary directly as the density of these connexion-rays transmitting it. In other words, therefore, the heat falling on a certain area normally exposed to the solar beams on different portions of the Earth's surface varies approximately as the portion of the ray's path produced included between the opposite surfaces of the Earth; *varies, i. e.*, as the cosine of the Sun's zenith distance.

But as the actual surface of the Earth directly behind the area perpendicular to the solar rays (*i. e.*, the area of the *shadow* of the latter) varies as the sine of the Sun's zenith distance, we have, at the equinoxes, the relative solar heat upon a certain area on any portion of the Earth's surface having the Sun in its meridian approximately determined by the quotient of the cosine, divided by the sine, of its latitude. Thus according to these circumstances the Sun's zenith distance would be very great near the Poles and very small near the Equator (or equal to the latitude of these places at the equinoxes); and therefore its cosine would be very small at the former and very great at the latter place. Also the sine of the Sun's zenith distance is very small near the Equator but very great near the Poles. The relative amount of heat at the Poles would therefore be nearly represented by the very small cosine divided by the very large sine, while at the Equator it would be represented by the very large cosine divided by the very small sine. Thus the actual solar heat falling upon a unit area near the Equator would be relatively much greater than by the current theory, while that received upon a unit area near the Poles would be much smaller than by that theory—which appears to agree precisely with the observed facts and account fully for the very low temperature of the Frigid Zones as compared with that of the Torrid Zone.

118. *Heat Transmission by the Secondary Connexions.*—It is reasonably supposable that, in accordance with the new theory, a greater degree of heat would be transmitted from the Sun through the primary connexions with the planets than through the secondary connexions with the satellites and other bodies. This

would naturally follow from the supposed comparative grossness, density, and strength of the former connexions. It appears probable also that the solar connexions with remoter bodies, such as the fixed stars, and perhaps some comets, transmit little or no heat. By the new theory the planet Saturn would at the present time be approximately in the same physical state as the Sun; *i. e.*, an intensely heated gaseous body, yet as our connexion with it gives no evidence of such heat, we are left to conclude that little or no heat is transmitted by such connexions. Moreover it is likely that heat transmitted through even the primary connexions would be chiefly, or perhaps wholly, in one direction, or from the primary to the derived body. And finally it would be almost self-evident that as the Sun contracted its volume and its crust became hard and cold, the heat supply to the primarily connected bodies would be very profoundly modified accordingly.

119. *Connective Theory of Light Distribution.*—In our investigations regarding the phenomena of light, much the same preliminary remarks apply as in the phenomena of heat. The light energy would travel only in the connexions; and that of the primary would be somewhat concentrated upon the derived body in the same manner as the heat energy. Of the actual amount of light at the surface of a heavenly body, however, the quantity we receive from it would not (at least yet) be any indication whatever; and for the same reason that the amount of heat we receive from it is no indication of its actual heat. The effect of the solar light rays as well as the amount of solar heat would be greater from a zenith Sun; but the same rate of diminution towards the edges of the solar connexion would quite probably not apply to light as to heat. Different

altitudes of the Sun do not appear to cause the same variations in the solar light as in solar heat. Our winter days are about as bright as our summer days, though the latter are much the colder; and similarly there seems to be nearly as intense a degree of daylight in the middle of the forenoon as at mid-day, although the latter is usually by far the warmer. Also there are times when clouds entirely cut off direct sunlight for days, during which the amount of daylight is not proportionately diminished. Our atmosphere evidently multiplies the light effects of the solar energy to a much greater extent than it does the heat effects of it; and this greater multiplication of light effects in our atmosphere manifestly causes an approximately equable light distribution over the day hemisphere. But probably the chief reason for this equable distribution of light is that the light rays are not concentrated like the heat rays, towards the center of the solar (or any) connexion, but are about equally distributed throughout its entire section—are, in fact, about as dense at the borders of the connexion as at its center. Heat or tension rays very probably vary as the mass to which they extend, because their function necessarily requires it. But the light rays, having a very different nature, would consequently have an entirely different function, having more to do with *surface* than with mass; and are therefore about uniformly mingled among the other rays throughout the whole connexion.

As for the necessary geometrical relations of space, they of course remain wholly unaffected by any theoretic deduction. The apparent angular size of a body, *e. g.*, would still be primarily modified by its distance from the observer; but it *may* also be secondarily modified by the *quantity* or *density* of the light rays issuing from it to the observer. It is well known that none of the so-called fixed stars presents any disc whatever, but a mere point of light. This may not, however, be altogether owing to the great distance, or to the smallness of these bodies. It is true that the distances of the fixed stars are comparatively vast, as is evidenced by their annual parallax (or rather its absence) as indicated by the diameter of the Earth's orbit. But it may be that the parallax is itself underestimated, owing to our approximately central position in the Sidereal System, and the absence or invisibility of all bodies beyond its confines.

Our sensations within terrestrial limits would again be no proper criterion for the interpretation of our sensations within celestial limits. Owing to the approximate constancy and uniformity of the terrestrial connective atmosphere, the law of inverse squares, with reference to light upon the Earth's surface, holds at least in most cases with a tolerable degree of exactness:—in *most cases*, and with a *tolerable degree of exactness*, because in some cases the law does not appear to account for the facts at all, as in the case of the glimmer of a taper being visible in the darkness for many miles, and even for a time apparently diminishing in intensity as the light is approached; and because in other cases there is only a partial accordance, as in the case of an object appearing only about four-fifths as large above our heads, as on a level with our eyes.*

120. *Horizontal Enlargement of Visual Objects.*—This phenomenon, in the case of heavenly bodies, such as the Sun and the Moon, has puzzled astronomers and physicists from the time of Alhazen, who observed it in the eleventh century, down to the present day; but it

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**Bull. Astron.*, April, '85.

still remains inexplicable. By the new theory the explanation of this fact would be simply that the horizontal rays of the connective atmosphere are more numerous at any time, or at any point of the Earth's surface, than the vertical rays are. This would follow, partly at least from the overlapping in the Earth's atmosphere of rays extending in opposite horizontal directions. The solar rays would communicate their light-action directly to other rays of the connective atmosphere which are parallel with them; and thus, in effect, the density of the solar rays would be increased by these parallel rays, and the visual effect would consequently be enlarged, for the same reason that it is enlarged by the greater density of the rays in the focus of a lens. The same reasoning also applies to any other object as well as to the Sun, Moon or stars. The greater number of horizontal than of vertical connexion rays transmitting its light causes a corresponding enlargement of the horizontal, as compared with the vertical, object.

121. *Question Raised by the New Theory.*—In general, as already stated, the necessary space relations mainly govern the apparent sizes of the heavenly bodies as viewed from any particular one. Thus we know that the Sun, Moon and planets are apparently smaller at their greater than at their smaller distances from us. But the question raised by the new theory is this: Does the light transmitted to us by all classes of heavenly bodies indicate their real relative dimensions, or their real relative distances as determined from their apparent dimensions? If Jupiter and an equal volume from the Sun and another equal volume from a fixed star, each shining by its respective light-rays, as we now see it, were all placed at the same distance

from the Earth, would they appear to us of the same size? Or, if placed where their apparent sizes were equal, would their distances from us be alike? If the new theory be the true one, it seems probable that they would not. For the remoter connexions are supposed to differ very materially from the less remote, the difference varying with the remoteness; and with such variation of the connexion, a corresponding variation in the character and quantity of light transmissible by it may reasonably be posited. As for the connection which this theoretical deduction would have with spectral analysis and the various colors of the fixed stars, although by no means unimportant, it may for the present give place to still more important discussions.

122. *Dark Transits of Jupiter's Satellites.*—A fact which probably lends support to the connective theory of light transmission is furnished by Jupiter's satellites. The two outermost of these satellites, and especially the fourth one, are frequently seen to cross the disc of the planet as dark objects, although their sunny sides are turned towards us at that time. At other times, the same satellites are seen to cross the planet's disc as bright objects; and the inner satellites, it appears, nearly always cross it as bright objects.

By the popular theory this phenomenon is explained as follows: "The perpetual whiteness of the second satellite, and the darkened tints of the others during transit (not to say in explanation of the casual appearances strange and unusual reported at other times) is due to differences in their relative *albedo*, as compared with that of Jupiter." And *albedo* is defined as the "relative capacity for reflection of diffused light from equal areas." * As the fourth and third satellites from the planet are sometimes dark and sometimes bright as they pass over the planet's disc, it is assumed that the sides of them presented to us in the latter case have a much greater capacity for reflecting the sunlight than the other sides. This explanation seems plausible, and it may be the correct one. It is liable to some objections, however, which seem to make it rather doubtful. It is shown that the albedo of the edges of Jupiter's disc is much smaller than that of its center. In consequence of this, the first, third and fourth satellites sometimes appear bright on the edges of the disc and dark on its center, while in every transit the second satellite is always bright. Now, one objection is that if the difference of albedo at the edges and at the center of the planetary disc be such as to cause *any* body to appear bright on the former and dark on the latter, it ought to cause *some* such effect during the transit of *every* body, which, however, we have in any degree failed to observe in *every* transit of the second satellite, and in many transits of the first and third. It would seem also that if the albedo of one side of a satellite, the third, *e. g.*, is so small as to appear black on the planetary disc, and that of the other side so great as to appear bright on that disc (Miraldi observed this satellite in transit as a dark spot, April 4, 1707, and as a white spot during the next transit, April 11), the black and the white transits ought to occur with about equal frequency; which again is not the case, as the dark transits of some satellites appear to be much less frequent than the bright ones. And still another objection seems to be that the albedo of *any* of the satellites should at *any* time be so much greater than that of the planet as to cause the former to appear white upon the latter. The edges of the satellites' discs would of course have a much less albedo than their centers, in a manner similar to the planet's disc. Yet these *edges* of the satellites' discs appear whiter than the *center* of the planetary disc upon which they pass, which, as a matter of fact, seems to contradict the actual measurements of these relative albedos given in the explanation, as well as those relative values of the albedos which would reasonably be expected under the circumstances.

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* Edmund J. Spitta, *Monthly Notices Royal Astronomical Society*, xlviii, No. 1, November, 1887, p. 32.

The following modification of this explanation is suggested by the new theory. The two outer satellites have the planes of their orbits inclined to the plane of the planet's orbit. This circumstance, together with greater distance from the planet, permits them occasionally to pass outside of the planet's connexion with the Sun as they revolve in their orbits, at which times they appear to us as dark objects upon the planet's disc. If Jupiter and the Earth revolved round the Sun in the same orbit-plane, obviously it would be impossible for us to see any of Jupiter's satellites pass across that planet's disc *outside* of the planet's connexion with the Sun, except for a few moments on the eastern or the western side of the connexion when Jupiter was near quadrature. But the plane of Jupiter's orbit is somewhat tilted to that of the Earth, so that the latter when about in conjunction with the former is nearly always either above or below Jupiter's connexion. Therefore, when the Earth and a satellite are both upon the upper or the lower side of that connexion, it is quite possible that the three bodies would be in a right *line*, at which time the satellite would appear as a dark spot upon the planet's disc. At other times the satellites would pass through the planet's connexion, and receiving its full effect of light and heat together with its own, it would appear about of the same, or even greater, brightness than that of the planet. The third satellite, being less distant, and its orbit less inclined, would pass outside of the planet's connexion at rarer intervals; and the second and first satellites not at all for the same reasons.

According to this view, each of the satellites would appear black upon the planet's disc, except when it passed through the planetary connexion during the transit; and the peculiar grayish or ashen hue frequently observed would be owing to the passage of the satellites through, or partially through, the edges of that connexion. This appearance in the case of the first satellite, whose inclination is so small that it would about always pass through the centre of the planetary connexion during its front transit may possibly be owing to its being viewed when the Earth and Jupiter are separated by a considerable heliocentric angle, so that it would pass over a portion of the planetary disc after it has passed through, or before it entered, the main part of the planetary connexion.

123. *Sunlight and Earthlight on the Moon.*—The illumination of the Moon's surface next to the Sun is not necessarily opposed to this view. Jupiter's satellites invaribly appear bright to us when not crossing behind, or in front of, the planet's disc; and this brightness can not always be due to the primary light of the planet. These satellites, therefore, appear bright by the Sun's secondary light just in the same way as our Moon. And we appear to have no evidence whatever that, to an observer on Venus, the Moon in its occasional tran-

sit across the Earth's disc does not appear at times as a dark object, and at others as a bright object, as it passed respectively to one side of, or through, the Earth's solar connexion; just in the same manner and for the same reasons that Jupiter's satellites appear so to us. The solar illumination of the Moon does not appear to us to be very intense. There is, in fact, no reason for believing that the solar illumination of the Earth would not quite probably appear more intense from the Moon than that of the latter does to us; and a slight deficiency of solar light upon one body as compared with another over whose disc it was making a transit would cause the former to appear comparatively dark. Now, besides being illuminated by direct sunlight (and possibly also by its own inherent light), the Moon would also be illuminated by earthlight. This earthlight would probably at the present time consist chiefly of reflected sunlight. But it *may* also consist partly of light inherent in the Earth itself. We know as little of the ultimate nature and transformations of light as we do of heat. As the latter may be manifested in the transformation of energies which are not heat, so the former may possibly be manifested in the transformations of energies which are not light. It seems not impossible, therefore, that along with the tolerably certain component of the earthlight upon the Moon. (*i e.*, the reflected sunlight) there may also co-exist a component consisting of a light originating on the Earth. The light reflected from the Earth to the Moon should obviously be much greater than the light reflected from the Moon to the Earth. Even by the current theory the former should be at least twelve times the latter. Yet, while we know that the Earth is very considerably illuminated by moonlight, the Moon at the most favorable conjuncture, as at or near new Moon, is little more than barely visible to us by earthlight.

By the new theory this fact would reasonably be explained by the structure of the Moon's primary connexion. It has already been intimated that heat would travel chiefly in the *primary* connexions, and almost wholly in a direction *from* the primary to the derived body. Light, however, embraces a higher range of phenomena; so that one kind of light might be transmitted by a connexion in one direction, while a different kind or degree of light might be transmitted by it at the same time in the opposite direction. But it seems very difficult to conceive that the *same* connective substance would at the *same* time transmit the *same* kind of light in *opposite* directions; for the reason that precisely the same connective lines or rays would be required for such transmission; and if these rays transmitted the light in *one* direction, it appears impossible that they could at the same time transmit that light in an opposite direction also. Now it is only reasonable to suppose that the Moon's primary connexion is *continually* transmitting light (and probably heat also) from the Earth towards the Moon; and, for the reason just stated, little or none of this light (and heat) could be transmitted back again to the Earth. While at the same time the solar light falling on the Moon, being supposably of a different kind, is readily transmitted Earthwards by that connexion. There is no evidence whatever by the popular theory that the solar light reflected from the Moon would be precisely similar to the same light reflected from the Earth. And by the new theory we have good grounds for believing that the solar light transmitted by the secondary connexion to the Moon is different both in quantity and kind from the solar light transmitted by the primary connexion to the Earth. Therefore, we seem to be quite justified in assuming that, of the light transmitted from the Earth to the Moon, very little, or none whatever, would be transmitted in a backward direction; which obviously would fully explain the faint visibility of "the old Moon in the new Moon's arms."

124. *The Moon's Sunlight on the Earth.*—At the time of a lunar eclipse, the lunar connexion with the Sun falls upon the Earth, which thus receives for the time the full benefit of the heat and light of this connexion, in addition to that of its own. As already intimated, the ratio or relation which the one connexion bears to the other is not determined. But if upon no other consideration than that of mass, the Moon's solar connexion would only be about one-eightieth of the Earth's; and by virtue of its secondary character, it would probably be much less than this. The additional amount of light and heat which at that time would be transmitted to us would therefore be scarcely perceptible unless special pains were directed to determine it. And it is from such determination that the quantitative and qualitative relations of the solar connexions of the two bodies will, in all probability, eventually be ascertained.

125. *Aberration of Light.*—In a Report to the British Association on Optical Theories, by R. T. Glazebrook, it is stated that Stokes "has given us an explanation of aberration by showing that we may suppose the Earth to move through space carrying the ether with it, the ether at some distance from it being at *rest;* provided that the motion thus produced in the

ether be irrotational, all the known phenomena of aberration will follow." This, however, would hardly be the case according to the current theory, for if the ether for a certain distance should be carried along with the Earth in its orbit, it would hardly fail also to be carried along with the Earth in its axial rotation. But by the new theory it is just what would actually happen. The planetary connexions upon the Earth are of course carried along by that body in its annual revolution, while they in no degree rotate with it about its axis, but are relatively fixed while the Earth rotates within them.

CHAPTER V.

ANOMALIES OF THE SOLAR SYSTEM.

126. *The Saturnian Ring.*—There are many curious and hitherto inexplicable anomalies in the Solar System which furnishes the strongest possible corroborative evidence of the new views thus far advanced. The planet Saturn and its ring is one of these—is indeed a standing witness the evidence of which alone should really be considered sufficient to establish the new theory. There is, properly speaking, no explanation of the curious phenomenon of Saturn's ring by the current theory. There are quite a number of alleged explanations, none of which, however, are tenable. The most common view is that the ring is composed of discrete particles of dust or tenuous vapor, similar to the substance of a comet's tail or the zodiacal light. This view is now accepted by the highest living authorities on the subject. The planet itself, on the other hand,

is supposed to be an ice-covered solid body.[*] How the planet became solidified out of the original vapors while the ring which had, to say the least, an equal chance to solidify, yet remains in the original vaporous state, is of course wholly inexplicable. And another inexplicable circumstance is the ratio of the centrifugal tendency of the ring-particles to the central attraction of the planet which acts upon them. The ring has been observed to rotate in a period of between ten and eleven hours, or in about the same period of time as the planet itself.[†] Yet this rotation of the ring, according to the present theory, implies a power of attraction of the planet upon the inner edge of the ring nearly one-and-a-half times greater than the centrifugal force generated by the ring's rotation; and at the outer edge of the ring the centrifugal force thus generated would be more than twice as great as the central attraction of the planet. It has indeed been supposed that the inner portion of the ring had a more rapid rotation than the outer portion in order that the balance of the forces might be thus preserved. But it is difficult to conceive how this state of things could be maintained for any length of time. And moreover, the rotation of the ring, just the same as the rotation of the planet, is indicated by the observation of spots. And the existence of spots upon a ring, the particles of which have very different rates of rotation, especially during an entire rotation of the ring, can hardly be regarded as within the limits of probability.

Some scientists are agreed that the ring is getting continually smaller in diameter, and will continue to grow inwards and eventually come in contact with the planet*; while others hold that the diameter of the ring-system is continually increasing at the rate of about 29 miles annually from the time of Huyghens.† Prof. C. A. Young states that "the most recent micrometric measures have failed to confirm Struve's suspicion that the rings are contracting on the planet."

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[*] The ultra-Jovian planets "are globes of solid ice, inclosing cores of rocky material and wrapped in vapor-laden atmospheres." Prof. A. Winchell, *World-Life*, p. 573.

[†] Herschel's *Outlines of Astronomy*, Art. 518.

By the new theory, Saturn's ring is simply the solid crust of the planet separated from it in the manner already indicated by the connective theory. It is in all probability continually receding from the planet, therefore expanding in diameter; and being thus subjected to an increasing centrifugal strain, it will yield eventually at some point and collapse into a satellite. There is little further to add to this explanation. Regarding the real attraction of the planet upon the ring, by the new theory, it may be stated that it would supposably be comparatively feeble. The crust of the planet as it separated into its present ring-form would carry with it a portion of the structurally developed connective atmosphere in which the function of attraction lies; the remainder of which on the planet's surface would supposably conform itself structurally, and therefore *functionally* with respect to gravitation, to the extremely different conditions supervening there after the crust's removal (see Art. 112, *b*). The same change in the connective atmosphere of the ring would take place probably by the extreme energy of its precipitation into the spherical form. Notwithstanding the general belief (arising mainly from the confusion of the popular theory) that the ring is multiple or made up of three or four separate rings, there is no real evidence

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*A. Winchell, *World-Life* p. 483; Otto Struve *Astron. Nachrichten* No. [illegible].

†Ray's *Elements of Astronomy*.

whatever that such is the case. There are indeed striations and bands of different colors; but this would quite supposably arise from the manner in which the ring is here conceived to have been derived, without involving any actual breach of continuity. The transparent inner portion of the ring, which we observe to be precisely analogous in substance to the solar coronal rays, the zodiacal light, and the tails of comets, is, by the new theory, nothing else than the ring's primary connexion with the planet, mixed, perhaps, near the ring, with some aqueous and other volatilized vapors. The main body of the ring is certainly sufficiently solid to cast an unbroken shadow upon the planet, and also to receive the shadow of the latter upon the side farthest from the Sun. The outline of this latter shadow, minutely scrutinized with powerful telescopes, has led astronomers to believe that the outer edge of the ring is rounded in form; precisely as the new theory would lead us to expect. Changes are continually occurring in the ring's structure, which is, no doubt, owing to its continual expansion. M. Stuyvaert of the Royal Observatory, Brussels, from drawings made February 8 and 15, 1887, and presented to the Royal Belgian Academy, shows that the black band corresponding to the Cassinian division, is encroaching on the outer portion of the ring, in a remarkable series of shaded indentations. Another portion is broken up into a series of bright white spots, by a number of dusky patches. Also there was observed three or four "large re-entering angles, like the teeth of a saw," on the inner margin. These observed changes have led to the belief, that the matter composing the ring is at present much less evenly distributed than usual. And, in fact, we really know not at what moment a serious break may occur, which would precipitate the awful catastrophe terminating the existence of the ring as such, and transforming it into the ninth Saturnian satellite.

127. *Comets.*—If the privilege of witnessing this grand catastrophe—the crashing together of billions upon billions of cubic miles of solid rock and earth, separated by more than 176,000 miles, or about three-fourths the distance of the Moon from the Earth—if the rare privilege of gazing with our mortal eyes, upon this awful convulsion of a world in the throes of a planetary birth be granted us, it may be that other bodies besides the offspring will be seen to engage our attention. In the extreme violence of the contact, vast fragments would probably have their parental connexions severed, and with a portion of these severed connexions clinging about them as an infant robe, these fragments would speed to distant worlds and systems as messengers bearing tidings of the nativity. These, although apparently wandering in all directions, yet would have their determined definite courses which they must pursue. The agents determining the comet's course would probably be one of the secondary connexions which yet remain attached to it. Some one of these connexions would lie more nearly in the direction of the comet's original projection than the others, and this one the body would follow. The leading connexion would thus become continually shorter, its substance accumulating upon the body; and, owing to the swift motion of the one and the material inertia of the other, it would fall behind the comet and form what is popularly called the "tail." This tail would of course increase in magnitude, owing to the continual accumulation of the connexion as the connected body was approached. Sometimes one or more subordinate tails are observed to extend from the body in different

directions; but quite probably these are only other secondary connexions carried by the comet, and into which a part of the accumulating connective substance finds its way, thus making them visible to us. Now the chances would be almost infinity to one against the original projection of the comet exactly in the direction of the connected body towards which the comet would move. The direction of projection would in fact be more or less to one side or other of that body. The comet, therefore, would not move directly towards the body approached, and as it moved past that body a gradual strain would come upon the connexion between the two, by means of which the former, in the course of several hours or days, would be swung around the latter until its motion was nearly in line with some other secondary connexion which it carried and which it would afterwards follow.

The substance of the tail, in obedience to its material cohesion and momentum, would also move round with the comet; and as the latter was more directly retained by the connexion, the former (whose momentum would be comparatively unchecked) would generally swing round it to the side farthest from the other body. Thus the normal position of the tail would usually be away from the Sun. But this position of the tail is not an essential feature in this theory. In fact, exact opposition of the tail to the Sun would rarely be the case, and probably rarely is the case. Indeed one comet at least has been observed whose tail pointed almost directly *towards* the sun.* In this manner the comet would recede much in the same manner that it approached; the connexion with the first body now elongating itself from the accumulated connective substance upon the body of the comet, just as the Earth's connexions with the planets become elongated when the Earth recedes from them.

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* *Nature*, XLI, 255.

After the comet rounded this second body it might return again to the first, or it might, subject to the guidance of still another secondary connexion which it would carry, move towards a third body, and then even towards a fourth, coming back by way of one or more of these, or perhaps directly to the first; or it may be that it would never return to the first, but would continue circulating around some others. In its wandering it would suffer a continual loss of motion from the friction of the connective medium through which it passes; and in all probability a plunge into the body towards which finally it would thus move, is the ultimate fate which would terminate its career.

All the peculiar and hitherto mysterious phenomena of these bodies thus fall in exact harmony with the new theory. But in still further confirmation of the new views, it has been observed that the substance forming the tail seems to rise in a continual stream from the side of the approaching comet nearest to the Sun; and, after ascending a certain distance, apparently sweeps behind the body. "It flows past the nucleus," says Dr. Huggins, "on all sides, still ever expanding and shooting backwards until a tail is formed, in a direction opposite to the Sun. This tail is usually curved, though sometimes rays or extra tails are also seen." This curvature of the tail, regarding which so very many unsatisfactory theories have been invented, it may here be remarked would be caused by the motion of the comet being in a different direction from that in which the leading connexion lies; the inertia of the connective substance and the comet's motion giving to the connective particles the observed resultant path. If the comet moved directly towards the Sun, *i. e.*, exactly in the direction in which the leading connexion lies, the tail would supposably be exactly straight during the approach of the comet.

It has been supposed by Siemens, Proctor, Langley, Huyghens and others, that the activity above noticed on the side nearest the Sun would be caused by the extreme solar heat driving occluded gases out of the solid nucleus; and then repelling them in a manner analogous to electric repulsion. But Professor Stokes has observed that this activity is just as pronounced in the cases of comets which have approached the Sun no nearer than our Earth does, or not so near; and these bodies, having no proper atmosphere, and subject, therefore, according to Professor Langley and others, to a temperature several hundred degrees below zero, such a theory, under such circumstances, can hardly be regarded as tenable.

Moreover, the evidence of the spectroscope goes to show that there is almost an exact similarity of composition and matter in comets' tails, the coronal streamers, the zodiacal light, the aurora borealis, and even the nocturnal phosphorescent glow occasionally visible over the sky. The eminent mathematician Euler was led by observation to put forward the theory "that there is a great affinity between these tails, the zodiacal light, and the aurora borealis." According to Angström and Otto Struve, a single bright line is seen in the spectrum of the auroral light, which indicates that it is a luminous fluid of a peculiar kind. Recently the zodiacal light has been analyzed by Angström "with a result," in the words of R. A. Proctor, "altogether unexpected, and at present almost unintelligible. *Its spectrum exhibits a bright line, and this bright line is the same that is seen in the spectrum of the aurora borealis.*" As to the "not merely amazing, but altogether unintelligible" phenomena of the tails of comets, the eminent spectroscopist, Dr. Huggins, remarks: "The spectroscopic evidence fails to give conclusive evidence on this point. Still . . . . the teachings of the spectroscope are in favor of the view that the self-light of comets is due to electric discharges." Subsequently,* he states that "we do not know the conditions under which these cometary appearances occur, but the generally accepted hypothesis attributes them to electrical action; . . . . to an electrical force which varies with the surface, and not like gravity, with the mass." And finally, in the words of R. A. Proctor once more,—"The spectrum of the Sun's corona exhibited the same bright lines as the aurora. . . . It is far from being unlikely that these long-vexed questions—the nature of the aurora and that of the zodiacal light, and that of the comets' tails—will receive their solution simultaneously."

128. *Meteorites.*—Meteorites would differ from comets in no respect whatever but their size. They would originate at the same time and in the same manner; the larger fragments being comets, the smaller, meteorites. The latter would circulate in the same manner as the former, and often, no doubt, round the same bodies. Indeed, it has recently been observed that comets are very frequently accompanied by immense streams of meteorites. Owing probably to their smallness alone these bodies are invisible to us, except upon very close approach; but each of them is, no doubt, accompanied by a minute tail or connective

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* In a Lecture at the Royal Institution, Feb. 20, 1884.

atmosphere in the same manner as a comet. If we are in need of further confirmative evidence, we have it in the bodies themselves which we see with our eyes and handle with our hands. Many meteorites—or aerolites, or comets, whichever we choose to call them—fall annually upon the surface of the Earth. We see them fall: we dig them out of the Earth in which their momentum has buried them; and we place them in our museums. What are they? They are simply pieces of rock, about in all respects similar to rock of our own world. "It has now been shown that meteoric stones sometimes contain pieces of essentially different rocks fused together and pieces of detritus—the wearing down of older rocks. Thus, as we know that sandstone is made of compacted sand, and sand itself was in some still earlier time part of rocks worn down by friction—when it is shown, as it has been by M. Meunier, that a sandstone with threads of copper in it (like some of our Lake Superior formations) has come to us in a meteorite, his conclusion that these stones may be part of some other world is one that, however startling, we can not refuse to consider." * And again, in the words of Camille Flammarion: "When sixteen years ago I published the last edition of my work—'The Plurality of Inhabited Worlds'—I did not expect to see the speedy confirmation that the progress of astronomy was to give to my essay, by allowing us, so to speak, to put our finger on the manifestation of planetary life. On the one hand those samples of other worlds—the aerolites—have brought us, in their composition, certain elements which play a very extensive *rôle* in life—such as oxygen, hydrogen, chloride of sodium, and carbon. The aerolite which fell at Orgueil (Tarn-et-Garonne) in 1864, brought us coaly matter—carburets that are due, like peat, to vegetable remains; the one which fell at Lance (Loire-et-Cher) in 1872, brought us salt. They had already brought us water in the form of hydrated oxide of iron. The worlds whence these fragments come, do not differ then essentially from our own." *

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* Prof. S. P. Langley, *Century Magazine*, Jan., 1887.

Another meteorite which fell at Mighei̋, in Russia, June 9, 1889, has been examined by M. Stanislaus Muenier. "About 85 per cent. of the rock was found to be attacked by acids, the portion so attacked being shown by analysis to consist mainly of a silicate of magnesium and iron having the composition of peridote. On the remaining 15 per cent. being treated in a current of dry oxygen gas, it readily took fire and burnt very brilliantly. The products of combustion, which were allowed to pass through the usual absorption tubes containing pumice and sulphuric acid and potash, showed that the meteorite contained nearly 5 per cent. of organic matter." †

Now, all of these remarkable facts are wholly inexplicable by the present theory. They are, indeed, so utterly at variance with the genesis of worlds, according to that theory, that prominent scientists, as the easiest way of avoiding the contradiction, strenuously deny that meteorites contain any organic traces whatever. Up to the present time the most reasonable theory of the origin of meteorites is that of J. Norman Lockyer and Prof. G. H. Darwin, which is that they are mere isolated condensations of the primordial vapor in the extreme cold of interplanetary space, brought into their present physical state by innumerable collisions with one another in meteoritic swarms.

* *Scientific American Supplement*, No. 175, p. 2787. † Nature XLI, 262.

Of course this theory utterly precludes the existence of any vegetable or organic substance in these bodies.

The theory of the origin of these bodies which is advanced in the present work is, on the contrary, completely in harmony with that of M. Stanislaus Muenier, of which a Commission of the Paris Academy said that he was justified in concluding "that all these masses once belonged to a considerable globe like the earth, having true geological epochs, and that later it was decomposed into separate fragments under the action of causes difficult to define exactly, but which we have more than once seen in operation in the heavens themselves.*

129. *Discrepancies of the Planetary Masses and Motions.*—It is probable that in the collapse of each planet-ring several comets and numberless meteorites would come into separate existence. It seems possible even that in the extraordinary violence of the falling masses, almost the whole ring might thus occasionally be broken up into such separate fragments. It is a reasonable geometrical deduction that the mass of each planet-ring should bear a definite ratio to the space through which the Sun contracted during the crust-formation, or, approximately, the space between the orbit of the resulting planet and that of the next preceding. According to this view, the outermost planets should be vastly larger than the innermost, and, in general, this is the fact. But still there are great discrepancies. Uranus and Neptune ought to be much larger than Saturn or Jupiter, whereas they are considerably smaller. Mars again should be larger than the Earth, whereas it is little more than a tenth as large. And the united mass of the Asteroids should

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* Prof. Holden, *Account of Progress in Astronomy in 1881*, p. 28.

be second to that of Jupiter, whereas it is much less than one-millionth of Jupiter's mass. By the present theory these discrepancies are unaccountable; by the new theory they are reasonably attributable to the dissipation of the ring-substance in comets and meteorites. In corroboration of this view, we observe that it is in those cases in which the mass-discrepancy is most marked that we meet with other irregular phenomena. For example, the axis of rotation of Neptune, Uranus and Mars vary the most from the perpendicular to the orbit-plane, which clearly indicates that these bodies are but larger residual fragments of the parent-rings, the axes of which have been tilted in the parting shocks of the portions ejected as comets and meteorites. However great the violence of the ring-disruption, if only the whole mass of the ring would aggregate into the resulting sphere, there could be no variation of the axis of rotation of this sphere from the perpendicular to the orbit-plane. It is quite probable that very large masses might be ejected from the resulting sphere without changing the inclination of its axis. But it is equally evident that when the axis of rotation is inclined from the axis of orbital revolution, an ejection of portions of the planet-ring as comets and meteorites is certainly indicated. Of course after the axis of the resulting sphere becomes once tilted it always remains so; and the succeeding satellites would have their axes of revolution at the same inclination. This would obviously be the case with Neptune and Uranus, the orbit-planes of whose satellites are almost perpendicular to the planes of the planetary orbits.

Another hitherto inexplicable irregularity of which this cometary ejection is a very plausible explanation is the extraordinarily small period of revolution of the recently discovered Martial satellites; that of the inner one being less than one-third the rotation period of Mars. Of this very unusual phenomenon the probable explanation is that the satellite is comparatively a small fragment of the planet-ring, the ejected portions of which by their final impact impressed upon it a certain amount of motion in a *backward* direction; and hence the body was drawn inwards by the elasticity of its connexion until its increased angular velocity generated a centrifugal force balancing the elasticity of the connexion.

It seems quite probable that the structure of the planet- and satellite-rings would differ very considerably; the substance of some being hard and elastic, while that of others would be soft and pliable, according with the various conditions to which their formation would be subjected. To the former class evidently would belong the three anomalous planets here mentioned, together with their satellites. It is also probable that, owing to their fragmentary nature, some of this class of planets and satellites, especially the smaller bodies, might at their origin have retained a portion or nearly all of their structural development, much the same, in fact, as the nuclei of comets. Upon this assumption, the two satellites of Mars may be mere blocks of solid rock. In such bodies the genitive process would supposably be exceedingly slow; the more so on those in which the greater degree of development was retained.

130. *The Minor Planets.*—According to the current theory, the minor planets or Asteroids, may have been owing to *a stratification* of the parent ring, from which "*it is quite* conceivable that numerous planets might

result."* Or the ring might have persisted until excess of perturbation "brought it into contact with the planet Mars,"† by which collision it was broken up into the Asteroids. Or Olber's theory of an exploded planet might be the correct one.‡ Upon reviewing which array of "contingencies," Prof. A. Winchell confidently remarks: "The possibilities of the nebular theory, therefore, deprive of all force any objection based upon the existence of a group of asteroids."

As the superior genius of its more recent supporter would lead us to expect, the last theory (of which Professor Winchell mentions his rejection merely in a footnote) comes the nearest to the explanation furnished by the new theory. The "grotesque" conception of a body liquifying, and even solidifying, around a gaseous nucleus, which Mr. Spencer "sets forth," is in exact accordance with the views here advanced. Had he only extended his conception a little further to the equatorial projection and eventual separation of such a solidified crust, and its final fracture and falling together through many millions of miles, Mr. Spencer would have arrived at precisely the same explanation of these bodies that is here offered—with only this exception: he had the solidified crust upon the *planet*, while the new theory would have it upon the *Sun*. If the substance of such a solidified planet-ring be supposed to be peculiarly brittle and elastic, in which supposition there appears to be nothing unreasonable, the violence of its collapse through such an immense space would amply account for the fragments which alone remain to tell the story. These are but the few the violence of whose ejection from the center of aggregation chanced to be only sufficient to separate their mutual connexions without severing those with the primary. The vast majority, having wholly severed their parental connexions (and probably their fraternal connexions also), had become wanderers among other and distant worlds.

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* A. Winchell, *World-Life*, p. 176.

† B. Pierce, *Gould's Astron. Jour.* ii, 18; G. Hinrichs, *Am. Jour. Sci.*, II, XXXIX, 54.

‡ Herbert Spencer, *Westminster Review*, LXX, 123.

131. *Comets from Satellite Rings.*—Would these wanderers ever return to the place of their birth? Probably not; for their family connexions would all, or nearly all, be severed; and therefore they would have no inducement to retrace their path. It would probably be otherwise, however, with the fragments escaping from the satellite rings. These, while severing their primary connexions with the planets, might still retain their secondary connexions with the Sun and some other planets; in the direction of some one of which they might perhaps be projected and so circulate around the Sun and one of these planets. The following quotation is strongly confirmative of this view. "The Pons-Brooks comet of 1883–84 is extremely interesting, as presenting the first instance (excepting Halley's comet, of course) of one of the Neptunian family of comets returning to perihelion. There are six of these bodies, with periods ranging from sixty-eight to seventy years. Halley's comet, the only large one of the group, has made many returns, and is due in 1910. Pons's comet, first observed in 1812, has now returned; Olber's comet of 1815 is due in 1889, and the three others, all of them small, in 1919–20 and 1922.

"I have spoken of them as Neptunian comets, *i. e.*, their presence in our system is known to be due in *some* way to this planet. The now generally received theory is that they have had their orbits changed from parabolas into their present shape by the disturbing action of Neptune. Mr. Proctor has pointed out certain unquestionable, though, I think, inconclusive, objections to this view, and he proposes, as an alternative, the startling and apparently improbable hypothesis, that they have been *ejected* from the planet at some past time by something like volcanic action.”[*] But although Mr. Proctor's hypothesis after all comes remarkably near to what has every appearance of being the fact, yet it seems certain that a comet could never return to the primary from the ring of which it was first ejected, and with which all its connexions are broken.

CHAPTER VI.

GENERAL METEOROLOGICAL PHENOMENA.

32. *Atmospheric Extension.*—We have noticed (Arts. 51, 52, 53) that the solar atmosphere extends to very great distances from the Sun's surface, and that this atmospheric extension is greater at times in certain directions than in others. From analogy we may deduce the same condition of things in the Earth's atmosphere also. It used to be the current belief that the utmost limit of our atmosphere did not extend to more than 50, or at most 100, miles beyond the Earth's surface. While this belief is still held to some extent, these limits have from time to time been extended in order to accord with more extended observation, until to-day we find some physicists ready to admit that it in all probability extends to the fixed stars!

[*] Prof. C. A. Young, *Nature*, XXXV, 117.

M. Mattieu Williams, in his "Fuel of the Sun," concludes "that the atmosphere of our earth is but a portion of a universal elastic medium;" and he states that Sir William Grove had also held the universality of atmospheric matter, and that Sir Charles Lyell expressed strong approval of this conclusion. Also Dr. C. W. Siemens in a paper on "The New Theory of the Sun."[*] independently arrived at the same conviction. "It is no longer held among scientists that the atmosphere of the Sun and its satellites are each limited in extent and bounded by clearly defined lines, the spaces between being void of matter, and hence vacuums; but on the contrary it is now admitted by nearly all physicists, that the respective atmospheres of all the planets, and of the Sun, are densest at the surface of the bodies, gradually growing more rare outward until at length but one substance constitutes it, and that substance a very rare one indeed."[†] And Prof. S. P. Langley mentions it[‡] as a remarkable speculation now gaining ground, and which Dr. Hunt strengthens with the name of Newton, that our atmosphere extends in ever-increasing tenuity, until it touches and merges into the atmospheres of other worlds. This though a mere chaotic diffusion, is still a somewhat close approach to the conceptions of the new theory. But the actual phenomena of the Solar System itself, such as the solar corona and the zodiacal light seems to furnish far more valuable corroborative evidence of these conceptions.

133. *Aerial Tides and Barometric Pressure.*—Passing over these phenomena here, because they are already discussed in Part I of this work, we may next examine

[*] *Nineteenth Century*, April, 1882.

[†] *Judge N. T. Carr, Humboldt Library of Science*, vol. V., page 25.

[‡] *Century Magazine*, March, 1885.

briefly, the causes of the regular variations of atmospheric pressure. For the reasons already stated (Arts. 56 and 57), the two primary connexions upon the Earth, or those connecting it with the Sun and the Moon, have a profound influence upon the atmosphere of our globe; piling it up at certain places and times, in waves called tides, while at other times they absorb its rarer gases outwards to greater distances from the planet's surface. Owing to the diurnal rotation of the Earth, all portions of its surface are successively swept over from east to west by these connexions; which, being material, would tend, in a degree, to drag the floating atmospheric particles through which they move along with them, and so give rise to aerial tides. The existence of these aerial tides would be indicated by the barometer, an instrument for measuring the *pressure*, and, therefore, supposably, the *quantity* or *mass* of air, at invariable distances, vertically above it; and that they are indicated by it, is now generally well known.

With respect to the Moon, A. Belikoff and M. Rykatschoff have concluded from a study of the anemograph records of St. Petersburg, that there are indications of a north and south movement during the lunar day, having one maximum and one minimum, and an east and west movement having two maxima and two minima, and therefore similar to the ocean tides.[*] With respect to the Sun, there are over the greater portion of the Earth's surface, two maxima and two minima of air-pressure in every 24 hours. The two daily maxima are in the morning and in the evening, about from 8 to 10 A. M., and from 8 to 11 P. M., and the two daily minima are intermediate, or at about 2 to 4 A. M. and 1 to 4 P. M. The observation made

[*] *Zeitschrift of the Ger. Met. Assoc.*, L., p. 373.

by the *Challenger* expedition in the Antarctic Ocean, and those made by the Norwegian Expedition in the north of the Atlantic, show only one maximum and one minimum in the 24 hours, the maximum occurring during the day and the minimum during the night.

Now, it is obvious at a glance that the morning and evening maxima would correspond to the passage of the east and west edges of the solar connexion, or bond, which, being attached to the atmospheric particles as well as to the land and ocean particles, would have a tendency, as it was transferred from one to another, to pile them up somewhat upon one another at those portions of the Earth's surface, where the strain of the connective filaments operated at right angles to terrestrial gravity, and where the only resistance, therefore, to such piling up would be the mutual friction of the atmospheric particles. The two minima, being about midway between the maxima, would evidently correspond to the center of the solar connexion, where the connective strain would be directly opposed by gravity, and where the rarer vapors ascend, and to the side of the Earth diametrically opposite to the center of the solar connexion, upon which no connective strain whatever is exerted. The single maximum of the higher latitudes, with respect both to the Sun and to the Moon, at about the middle of the respective day of each, just as obviously corresponds to the north and south edges of their respective connexions, the central or denser portions of which pass but once daily over any place, and which would cause a slight movement of the air particles in latitude, as the east and west edges did in longitude; and the single minimum would likewise correspond to the opposite side of the Earth upon which were no solar or lunar connexion. It seems quite unnecessary to dwell further upon this, as the agreement of the actual phenomena with the theory is apparently complete.

134. *Cloud Zones.*—In further corroboration of the general theory, it may be noticed that the barometric pressure is somewhat greater within the tropics, and that the clouds are distributed in zones parallel to the Equator. M. L. Teisserence de Bort has shown, by charts based on observations made at 700 stations, and on an immense number of observations collated by the Meteorological Office in Paris, "(1) that there is a marked tendency in all months towards a distribution of cloud in zones parallel to the equator; (2) when disturbing influences are eliminated, it is seen that there is a maximum amount of cloud near the equator; that there are two belts of slight nebulosity from 15° to 35° of north and south latitude, and two zones of greater cloudiness between latitudes 45° and 60°, and that beyond this (so far as can be judged from observations in the northern hemisphere) the sky appears to become clear towards the Poles; (3) these zones have a marked tendency to follow the march of the sun's declination; they are transferred towards the north in spring, and towards the south in autumn."*

It would also be inferred from the new theory that the upper currents of air of the equatorial belt would continually follow the movement of the primary and planetary connexions over the Earth's surface—*i. e.*, from east to west; and this by the best authorities is now admitted to be the fact. E. Douglas Archibald, of the Krakatão Committee, says: "Theory is naturally, perhaps, though still somewhat singularly, silent

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***Nature*, XXXVI, pp. 15-16.

as to what is supposed to be the motion of the air in the upper regions of the belt bounded by 15° on either side of the equator. Ferrel's equations are not very satisfactory for this space. . . . That the wind there, however, still maintains its westward component under the normal conditions which accompany the north and south trades is plain both from Mr. Abercromby's and other observation." *

135. *Sky-glows.*—An extraordinary terrestrial phenomenon seems to have placed this westerly equatorial current beyond dispute. On the 26th day of August, 1883, occurred a frightful eruption of the volcano Krakatão, on the island of Java, in which 50,000 people lost their lives. Enormous volumes of smoke, dust and ashes were ejected upwards into the air for a distance of many miles. Almost immediately afterwards appeared in the surrounding region the peculiar sunset glows which afterwards became so prominent nearly all over the world. Here is the sequence of the first appearance of this phenomenon in different parts of world, as given by Mr. Ralph Abercromby:

"On August 26, the day of the eruption, ashes, lofty haze, or red twilights, are reported south of the equator, nearly 20° of longitude west of Java, from one station in Sumatra, just north of the line, and from near Formosa.

"Next day, the 27th, similar phenomena were reported from many stations in the Indian Ocean, south of the equator, as far west as Mauritius and the Seychelles, while north of the line strange appearances were reported for the first time in Borneo and Ceylon.

"On the 28th, the haze and abnormal glows had extended to Natal on one side and Japan on the other.

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* *Nature*, XXXVI., p. 153.

"No important extension of the area is reported on August 29; but by the 30th unusual coloration of the sky is reported from various parts of the South Atlantic and Guiana, and, what is specially noticable, from about the Cape Verd islands, north of the equator.

"On the 31st, another station in Brazil, and also a West Indian island, report a strange look about the sun or sky; while on September 1 the same was noted at Guayaquil, on the west coast of South America; and in a quite unexpected locality, far away from there,—New Ireland.

"September 2 was characterized by an outburst of colored suns all over the northern provinces of South America; while between the 3rd and 4th of the same month the glows extended across the Pacific, both north and south as far as the Society and Gilbert Islands, and were reported from two stations in New Britain.

"By September 5 the Sandwich Islands were reached while the outburst of glows in Southern India did not commence till about the 6th to 8th of the same month.

"The northward extension of the dust all this time was very small, and not widespread. Isolated phenomena are reported from Formosa on August 26, and from Japan on the 28th, but I am unable to say whether the glows which appeared in the Sandwich Islands on September 5, had come *via* Japan, or across South America.

"Thus the general system of the dust-flow appears to have been very simple. The great dust-stream was carried for the first twenty-four hours by the normal easterly upper currents over the south-east trade, at the extraordinary rate of about 120 miles an hour, but hardly extended north of the line. Three days after the eruption we find the products of Krakatão in Guiana, the South Atlantic and also north of the line in the Cape Verd Islands. Just to the south of the latter we know that the south-east trade with its attendant upper currents, crosses the equator. Then all the north of South America was invaded; and six or seven days after the first outburst, the Pacific Islands—south of or on the line—were also overshadowed.

"In fact we may say, that the great streams of Krakatão dust was carried nearly round the world by the usual upper winds of the south-east trade, in which the dust was first ejected, at a rate of about 120 miles an hour, and that the dust spread very slowly either north or south of the main current." *

The most serious objection that has been urged against this explanation of the sky-glows of 1883-4, is the enormous velocity with which the volcanic ejecta must have been carried round the world; a greater velocity, in fact, than had ever before been observed in atmospheric currents. A partial explanation of this was that the velocity of atmospheric currents near the Equator was shown by observation to increase with the elevation. But of this fact of greater aerial velocity at greater elevations there seems to have been no explanation offered, as Mr. Archibald in the foregoing quotation has observed. By the new theory, however, the explanation is obvious at a glance. The rarer and more volatile aerial fluids which ascend to the greater elevation are more easily detained by the nearly stationary connexions of the Earth. As our planet performs its diurnal rotation, the connexions falling upon it remain absolutely fixed so far as that rotation is concerned. The lower and grosser strata of air freely permit

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*Nature, XXXVI, pp. 86-87.

the passage through them of this connective substance, but the higher and higher strata, becoming more and more tenuous and of less and less momentum, would more easily suffer detention by the connective substance, until, at very great elevations, the aerial tenuity would almost approximate that of the connective substance itself, and so suffer complete detention. Thus while the Earth revolved from west to east in every 24 hours, the upper aerial regions remaining nearly or wholly stationary (but gradually partaking of the Earth's rotation more and more as the Earth's surface is approached) would seem to an observer near the Equator to be moving with great velocity from east to west. And, therefore, when the equally tenuous and volatile smoke and dust of Krakatão were ejected into these slowly moving or nearly stationary upper regions it would be partially retained by them, and the Earth's surface revolved under it towards the east until, in the course of a few days, it had gained an entire revolution upon the ejected substance. Thus the extremely rapid apparent westward movement of the ejecta appears to be fully accounted for, while the north and south movement of the same would just as obviously require a much longer period because it would be accomplished only by diffusion and occasional local currents.

The remark is here ventured that epidemic diseases, such as influenza, cholera and the Black Plague (the material cause of which, for anything we know to the contrary, may be partly at least the accumulation in our atmosphere of a peculiar connective substance from the inter-planetary spaces), are probably transmitted over the Earth's surface almost precisely in a similar manner.

CHAPTER VII.

THE OCEAN TIDES.

136. *Comparison of the Two Theories.*—The same general explanation applies to the ocean as to the aerial tides. The two tidal waves would correspond to, and, on the open ocean, would nearly always accompany, the east and west edges of the lunar or the terrestrial primary connexion. And the two tidal troughs or depressions would correspond to, and generally accompany, the central meridian of the connexion (where the tide-raising force was directly opposed by gravity,) and the opposite meridian upon which the connexion did not act. Owing to the far greater density of water, and the ease and rapidity of its wave transmission, these tidal waves and depressions would quickly assert themselves over the entire ocean surface contiguous to each connexion border, and so overwhelm or mask the minor single wave which but for this circumstance would alone take place in the higher latitudes.

According to the popular theory of the tides, the the tidal wave is raised by the attraction of the Sun or Moon upon the central meridian directly beneath its orb, where it is directly opposed by the 12-million fold more powerful terrestrial gravity (Art. 89); whereas, by the new theory, the tidal wave is raised at the east and west borders of the Earth as viewed from the tide-producer, and where the tide-raising force is at right angles to, and therefore almost wholly unopposed by, the Earth's attraction. According to the popular *theory*, tidal waves and depressions are nearly always delayed for relatively great periods; the "establishment" or "age of the tide," *i. e.*, the interval of time between the transit of the body which originates a tide and the appearance of the tide itself, being supposed to vary at different places from a few hours to several days. While, strangely enough, the "tidal interval" or difference between the time of high water and that of the transit of the tide-producer immediately preceeding the tide, is known rarely to exceed seven hours, the average "tidal interval" being about six hours. Thus the "age" of the tide on the east coast of the United States is held to be about a day and in Cumberland Sound, British America, nearly two days; while the new theory would make the age of the tide at both places about six hours, corresponding with the actual observed angle of separation of the tidal wave from its producer. As for the ports upon a western continental coast, such as London, they would by the new theory, have no proper tide at all, but simply a branch or secondary wave spreading outwards from the proper tidal wave in accordance with well-known hydrostatic laws.

137. *The Greater Tidal Wave Due to the Sun and the Lesser to the Moon.*—Now if the new theory be the correct one, the solar tide ought to be nearly two and a half times as great as the lunar tide because the strain of the solar connexion upon the Earth is nearly two-and-half times as great as the strain of the lunar connexion. In passing, it may be remarked that the aerial tide due to the Sun is much greater, or is much more noticeable, than the lunar aerial tide, which, very obviously, is in direct opposition to the current theory and in favor of this view. In any event, this is just what the new theory teaches, not only with respect to the aerial tides, but also with respect to the oceanic

tides. The greater tidal wave would be owing to the Sun, and the lesser would be owing to the Moon. The terms of the ratio of the two tides would be almost precisely the same (though very differently derived) in the one theory as the other, but the new theory takes the reciprocal of the old for the new ratio. The pull of the Earth's connexion with the Sun is such as to deflect the Earth from a tangent to its orbit about 0.01 ft. in one second of time. The pull of the Moon's connexion with the Earth is such as to deflect the Moon from the tangent to its orbit about 0.00447 ft. in one second. These pulls, by the new theory, represent exactly the tide-raising values of the connected bodies respectively upon the Earth, and, therefore, the solar tide-raising power is more than twice as great as the lunar tide-raising power, or the two have just about the same ratio as the actual tides.

Now, the angular difference between the solar and the lunar tide at no time exceeds six hours, according to either theory. But—what is of the utmost importance in this connection—it will also be observed that the angular difference of the effective directions in which the tide-raising powers of the two theories act, is also just six hours. From which it clearly follows that a change from the adoption of the central meridian of the Earth's hemisphere next to the tide-producer as the line of application of the tide-raising power to the adoption of the east and west edges of that hemisphere as the lines of application of the tide-raising power—must necessarily involve the adoption of the supposed lunar tide as being due to the Sun, and of the supposed solar tide as being due to the Moon. In other words, if the lunar and solar tides are on the average six hours *apart, and if* an error of just six hours is shown to be involved by the present theory in the origin of each tide, a correction of the error would put the lunar tide exactly in the place of the solar tide, and *vice versa*. Now the new theory does involve a difference of just six hours in the place of origin of each tide, as indicated by the present theory; and, therefore, it follows that the adoption of the former instead of the latter theory involves the substitution or transposition of each tide as an effect of the producer of the other.

138. *Possible Objections Answered.*—No doubt it will be at once objected to this view, that the tide now ascribed to the Moon can not be assigned to the Sun, for the reason that the two bodies do not travel at the same angular rate around the Earth, and, therefore, the Sun would not keep pace with the tide as it ought to do if the new theory were correct. Now, it is a fact that the tidal wave approximately keeps pace with the Moon. The latter body comes to the meridian of any place about an average of 49 minutes later on any particular day than on the preceding day, and the tide also appears at any particular place in approximate parallelism with the Moon's meridian passage at that place, while, of course, the Sun comes to the meridian of any place once in every 24 hours, and, therefore, out of all conformity to the appearance of the tides.

In reply to this apparently very serious objection, we may first note that there is only *one* tidal wave upon a hemisphere of the Earth at one time and but *one* also upon the opposite hemisphere at that time. In other words, any place upon the Earth has no more than two high tides and two low tides in any 24 hours; and this although, according to either theory, there are two tide-producers each of which would cause two high tides and two low tides in about that time. It is to be borne in mind that a tidal wave due to any tide-producer would cover very nearly a whole oceanic hemisphere of the tide-bearer at once. We know this from the fact that, at any particular place it requires about 5 hours for any tide to flow and about 6 hours for it to ebb. Now since there are two tide-producers each of which alone would cause two tidal waves, it follows that the utmost angular distance between the crest of one wave and that of some neighboring wave would not exceed 90°; and even at this maximum distance, the one would lap considerably over the other. In fact it appears that, even at this maximum distance, the crest of each wave unites with that of the other at some intermediate point to form a single tidal wave with a single apex at that point; and thus it happens that, with the two tide-producers, there are but two tidal waves. In the more elegant words of Sir John Herschel—"The actual tide-day, then, or the interval of the occurrence of two successive *maxima* of their superposed waves, will vary as the separate waves will approach to or recede from coincidence; because when the vertices of the two waves do not coincide, their joint height has its *maximum* at a point intermediate between them."

Here, then, is the explanation of the nonconformity of the tidal wave with the Sun's apparent motion. The wave does not, as a matter of fact, conform generally either to the Sun's apparent motion or to that of the Moon: it nearly always conforms only to the apparent motion of a variable point either between the two bodies or between their tides. Let us suppose for illustration that the Sun and the Moon are together; in which case the tidal wave conforms to the position of both bodies. Suppose now that the Moon moves some 30° in advance of the Sun; then the apex of the tide would also move in advance of the Sun conformably to a point between the two bodies. This would obviously cause a lagging of the tide behind the Sun at any particular place upon the Earth. If the Moon moves 90° in advance of the Sun, then the apex of the tide also moves still farther in advance of the Sun, and there would be still further lagging of the tide behind that body. As the Moon moved away from the Sun, the height of the tidal wave continually diminished; so that when the former was 90° in advance of the latter, the tide was at its minimum height. After the Moon's distance from the Sun exceeded 90°, the former apex, still advancing, would continue to sink still lower, and a new apex would form still further in advance in conjunction with the opposite solar tide. This new apex would increase in height and advance rapidly with the Moon at first, but more slowly as the Moon's distance from the Sun neared 180°; at which positions the tide would be again at its maximum height, and its apex would again conform to the positions of, both bodies. Thus, between conjunction and opposition of the two tide-producers, there is a continual advance of the tidal apex from the Sun, and therefore a continual lagging of the tide behind the Sun at any particular place upon the Earth. In fact, in half a synodic revolution of the Moon, or about 15 days, the tidal apex advances from west to east around the Earth, a distance of 180°, or just the same distance that the Moon moves around it; so that the Moon and and the tide, while not maintaining a parallel conformity throughout, yet move around the Earth at precisely the same rate on the average. From opposition back to conjunction, the same reasoning would apply; and just the same movement of the opposite tidal wave around the Earth would take place as that of the one we have considered. Many circumstances would modify this general result, however, such as the varying distances, of the tide-producers, implying their various angular velocities around the Earth, and consequently various strains of their connexions upon the waters causing various heights of the tides.

Generally, according to this theory, the greater amount of lagging of the tides behind the Sun would be at the Moon's quadrature, or when the tide is at its minimum height, and the least amount of lagging of the tide would be at the syzygies, or when the tide is at its maximum The amount of lag would thus theoretically vary from a few minutes up to about two hours in a period of 24 hours, which appears to be fully borne out by actual observation.

139. *Corroborative Evidence from Inland Sea Tides.* —It is only on the ocean surface, however, that, at great angular distances, the crests of the lunar and of the solar tides would blend into one common apex. Upon lakes and inland seas, tides would be produced by one only of the two bodies when they are about 90° apart, because the area of the water surface is so small that when one body would be in a position to produce a tide upon it, the tide-raising effect of the other body would be shut out by the land surface surrounding the water. Thus, under these circumstances, the tide of one body would be isolated from that of the other, and if the new theory is the correct one, the solar tide would be the larger of the two, and would occur regularly twice every 24 hours.

Now, upon most lakes and inland seas the tides are so small, owing to their small areas, as almost to escape detection. Undoubtedly the most favorable place for making an observation of this kind upon the whole surface of the globe is the Mediterranean Sea, and upon this great inland sea these very facts have been observed —to the no small astonishment of the physical astronomer. On the 8th of August, 1887, M. Héraud read a paper before the Paris Academy of Science on "The Tides of the Tunisian Coast." The following quotation is made from an abstract of this paper in *Nature* of August 18, 1887 (vol. xxxvi, p. 383).

"The observations made during the hydrographic survey of the coast have enabled the author to study the tidal movement, the existence of which in the Gulf of Gabes and on the adjacent seaboard has long been demonstrated. These tides appear to be the most important and regular in the whole Mediterranean basin; but they are perceptible only on the section of the coast south of Mehediah. They continually increase in magnitude as far as Gabes, where they acquire a maximum of 2 metres at the mean spring tides, thence decreasing to 1 metre at Zarzis and on the Tripoli frontier. *The tidal wave appears to come from the east, the mean period being apparently about 24 hours.* All the observed circumstances would seem to show that *the relation of the lunar to the solar wave is less than that of the absolute actions of the sun and moon.*"

Thus, then, are the new theoretic deductions in another important instance fully borne out by actual observation. Of course we are not without other observations corroborating these deductions. As already noticed, the chief aerial tides which are indicated by the barometer are all traceable to solar action;[*] while the aerial tides traceable to the lunar influence is so very faint as to be barely perceptible; although according to the current theory, the lunar tide, aeriel as well as oceanic, ought of course to be more than twice as great as the solar tide.

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[*] It appears that recently the aerial tides are ascribed to solar and terrestrial radiation, rather than to the Sun's tidal action. The Sun's heat undoubtedly would produce some effect upon the Earth's atmosphere; but nevertheless the effect of the Sun's tidal action would still be most promi-

140. *Discordance of the Present Tidal Theories.*—On the whole, it now seems that all serious objection to this connective theory of the tides is fairly and squarely met. While on the other side, the confusion and admitted inadequacy of the present tidal theories lend it no little support of a different character. "There is no present theory of the tides which answers all the requirements of tidal phenomena. The 'Wave Theory' of Sir G. B. Airy fails in its application to the open ocean. The 'Dynamical Theory' of Laplace fails in its application to shallows, estuaries, and rivers. And the 'Equilibrium Theory' of Newton and Bernouilli is pronounced simply 'contemptible' by Sir G. B. Airy."*

nent, and clearly traceable. Indeed this is shown to be really the case by M. A. Angot of the French Meteorological Office, who has published in the *Annales* of that Office, a very careful discussion of the diurnal range of the barometer, based upon the best available data for all parts of the globe. "After having given the mean range for each month and for the year, he has calculated the amplitudes and phases of the first four simple harmonic oscillations into which the complex oscillation of the barometric diurnal range may be resolved, and which may be considered as the resultant of the superposition of two waves of different origin and character. One of these, which the author terms the thermic wave, is of a more or less complicated form in appearance, and is easily explained as being produced by the diurnal variation of temperature, and by the differences that this variation presents between neighboring stations. The other, the principal semi-diurnal wave, for which he has given the numerical law, presents a much more simple form, and is not at all affected by local conditions. It is possibly produced by the calorific action of the sun upon the upper strata of the atmosphere; but, as the author states, this is still only an hypothesis, and the theory of this part of the phenomenon remains to be established."—*Nature*, XLI, 449.

*Prof. Alexander Winchell, *World-Life*, p. 225.

CHAPTER VIII.

TERRESTRIAL ELECTRICITY AND MAGNETISM.

141. *The Idea of an "Immaterial Substance."*—Let us examine more closely the conception of the Earth which the new theory implies. Our globe revolves annually around the Sun in what is called the plane of the ecliptic; it also rotates diurnally upon an axis which is always inclined from a perpendicular to this plane at an angle of about 23½°. The popular theory is that the Earth is substantially isolated from all other heavenly bodies; that it is held to the Sun by a so-called force of gravitation, or immaterial thing which is capable of acting upon it through millions of miles of perfectly empty space; and that the heat of the Sun and the light of the Sun and stars, which are diffused equally in all directions, are transmitted to it by the vibrations of an imaginary and unaccountable universal ethereal medium, which the researches of recent years have compelled a belief in as an indispensable vehicle for the transmission of heat and light phenomena. It seems quite impossible for the mind to grasp any conceivable mechanism which would serve as a basis for such conceptions; and, as an apparent consequence, they lead to a great deal of mental confusion. It may be, as Prof. Huxley says, that "an *immaterial substance* is perfectly conceivable," and "may have any conceivable properties;" which propositions, he says, "may be affirmed with complete dialectic safety inasmuch as they can not possibly be disproved." But whatever

may be the "dialectic safety" of their affirmation, their essential elements seem utterly to elude the grasp of the intellect. An *immaterial substance* appears to be about as intelligible or conceivable as a *cold heat*, a *void plenum*, or a *black white;* each of which, in plain words, is a contradiction in terms, and can not, therefore, be regarded as conceivable in any proper sense of that word. But such are, nevertheless, the so-called conceptions by means of which many phenomena are sought to be interpreted, and such appears to be that in the popular theory regarding the Earth's connection with the Sun.

142. *Differentiation of the Earth's Connexions.*—According to the new theory, the Earth is the center of myriads of material connexions or bonds with other heavenly bodies. These envelop it on all sides in what may be termed a connective atmosphere, which, as far as the daily rotation of the Earth is concerned, remains fixed, and in which the body of the Earth and the atmosphere proper, or the air, performs its diurnal rotation. The connective atmosphere, as already intimated, is much rarer than the air; so much so, indeed, that when the air is about all extracted from a space near the Earth's surface, it is said to be an empty space or vacuum, although all of the connective atmosphere which the space originally contained still remains in it. Therefore, the friction which the rotation of the Earth in the connective atmosphere would engender, would reasonably be very small indeed; but still, the connective atmosphere being material, there is supposably a certain amount of friction. Now the individual connexions which make up this connective atmosphere are supposed to differ materially from one another, and the degree of difference very probably

corresponds to the degree of relationship of the connected bodies with the Earth. Thus the grosser connexions would be those with the Sun and the Moon, which are respectively the parent and offspring of our world, the next in grossness would be those with sister planets and our grand-sun, then those with our grand-grand-sun, sister suns, and the satellites, and so on back to the remote bodies of the Sidereal System, and perhaps even to innumerable other sidereal systems.

But, as already intimated elsewhere, although the connexions are supposed thus to differ materially from one another, it is not implied in this that any individual connexion is composed of a form of matter uniformly different from that of any other connexion. On the contrary it is reasonably supposable that each connexion, and especially each of those with the bodies nearly related to us, is made up of many different forms of matter having different degrees of grossness. These forms we may designate by the term *rays*, such as tension rays, heat rays, light rays, etc. The supposition involves only that the grossest rays have a tendency to diminish with diminished degrees of relationship, until there would be in the connexions with very distant bodies extremely little, if any, of such rays, and chiefly or only those more delicate rays which transmit to us light, or perhaps only the more delicate kinds of light, or even still more delicate kind of motion, of the existence of which we have no perception whatever. The most delicate rays may exist in the grossest connexion, but not so the grossest rays in the most distant connexions.

Another probable circumstance is that the nature of the connexions changes rapidly with the degrees of relationship, and especially with the nearest degrees, so that the Earth would be profoundly affected, at least with respect to other phenomena than light, only by the nearest related bodies. Now, all of the bodies nearly related to the Earth, such as the members of the Solar System, of its sister systems and of the primary around which the latter immediately revolve, are all supposed to lie in, or very nearly in, the plane of the ecliptic. The Earth, in its diurnal rotation, is continually swept by the connexions of these bodies, and we shall shortly find reasons for believing that it is to the variations of these connexions, or of certain elements of them, or to some influence clearly attributable to them, that the hitherto mysterious phenomena of terrestrial magnetism are due. And this not only on theoretic grounds, but also from the actual observations of the most eminent students of this subject.

143. *Relation of the Magnetic Poles to the Planes of the Earth's Motions.*—If a straight line perpendicular to the plane of the ecliptic should pass through the Earth's center, it would pierce the Earth's surface in the Northern Hemisphere 23½° on one side of the geographic pole, and in the Southern Hemisphere 23½° on the opposite side of the geographic pole. Now, when we know from actual observation that this is almost exactly the position of the Earth's magnetic axis, the North Pole of which is near the Arctic Circle in North America, and the South Pole of which is near the Antarctic Circle south of Australia, it seems unequivocally to refer the cause of the Earth's magnetism to the plane of the ecliptic, in which, as we have seen, those connexions lie to which, by the new theory, the electric fluid is supposed to be attributable.

Without further preface, the explanation of terrestrial magnetism suggested by the new theory is as follows:—The connexions of the bodies mentioned are continually varying in quantity upon the Earth, owing to continual variations of the distances of these bodies from the Earth, and, to a certain extent, perhaps, to other causes. The connective fluid of these connexions penetrates the Earth crust to an indefinite depth; and, if aggregating upon the Earth, it would be liberated in that crust, and, flowing at first in the direction of least resistance, *directly away* from the ecliptic plane in which the pressure is exerted upon it, would thus give rise to the observed earth-currents. *Away* from the ecliptic plane means either north or south of it; and really it would make little practical difference which direction is taken, but the path'sbeing once determined would make it easier to follow thereafter. In the case of the Earth, either all, or the greater portion, of the fluid at first appears to have traveled northwards; and thus, perhaps by mere chance, became permanently established in this direction. As the connective fluid continually pours inwards upon the Earth and northwards through the crust, and as it approaches the farthest point of that crust from the ecliptic plane, it becomes concentrated owing to the curvature of the Earth's surface, and partially escapes from the crust into the atmosphere. This partial escape of the fluid would continue and gradually increase in amount until the farthest point of the crust was reached, where the remaining and relatively greater portion would escape, and thus establish the North Magnetic Pole. The atmosphere at the north becoming saturated, the fluid would find its way southwards on all sides of the Earth, and crossing the Equator would be again concentrated by the Earth's curvature, and therefore would partially escape into the Earth's crust, and so establish the

South Magnetic Pole. The earth-currents again flowing northwards towards the North Magnetic Pole, the circuit would be complete. If the connective fluid be leaving the Earth, instead of arriving upon it, the connexion suffering the tension would be supplied from the earth-currents, just as in arriving it was supplied to them. This extremely simple explanation would be still simpler if the Earth had been considered as we find it, and not as at the beginning of the formation of the electric circuit. But the current once established either in a north or a south direction would thereafter be permanently established in tha tdirection; as the flow in one direction or the other would be continual.

It appears to be the belief at the present time that the electric fluid ascends at the Equator and there divides into north and south streams which descend into the crust near the Poles. Actual observation, however, appears to contradict this view. Thus from the Report of the magnetic results of the Challenger Expedition it is found:—"(1) That in islands north of the magnetic equator, the north-seeking end of the needle is generally attracted vertically downwards, and horizontally towards the higher parts of the land; (2), south of the magnetic equator the opposite effects are observed, the north-seeking end of the needle being repelled: in both cases by an amount above that due to the position of the island on the earth considered as a magnet." * This seems clearly to show that, if north of the magnetic equator the currents are *ascending*, south of it they must be *descending* in order to produce the observed opposite effects upon the needle.

144. *The Earth a Magnet.*—In fact the Earth is a mag-

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* *Nature*, *XLI*, 106.

net, and its electric currents are apparently the perfect analogues of those of a magnet. If we take a common bar magnet and place over it a sheet of paper or glass, upon which is sprinkled promiscuously some iron filings, a tendency of the filings will be noticed to arrange themselves in determinate lines. Being hampered by the friction against the paper they cannot freely follow this tendency; but by tapping the sheet they are released for a moment and are thus permitted to obey the magnetic force. They thus become arranged in beautiful curves or semi-ellipses extending from pole to pole. These are the "magnetic curves" which have been so long familiar to scientific men. Prof. John Tyndall tells us that "the aspect of these curves so fascinated Faraday that the greater portion of his intellectual life was devoted to pondering over them. He invested the space through which they run with a kind of materiality; and the probability is, that the progress of science by connecting the phenomena of magnetism with the luminiferous ether, will prove these 'lines of force' as Faraday loved to call the magnetic curves, to represent a condition of this mysterious substratum of all radiant action."* Now this is just what the new theory does, except that instead of an imaginary luminiferous ether we have the fluid of the Earth's connexions. The ground-currents of the Earth flowing northwards and escaping into the air chiefly about the North Magnetic Pole manifest themselves in the "auroral circle." The Northern Lights would therefore be the electric currents of the Earth ascending into the air preparatory to their journey southwards in that element. Their visibility would be owing to their concentration in the north by the Earth's curvature; but as they move southwards, they spread over a greater area, become more diffused, and so become invisible. It is this electric flow southwards through the air that would determine the direction of the magnetic needle; which is simply another magnet almost exactly similar to the Earth, having similar electric currents circulating northwards through *its* surface, from which they escape into *its* atmosphere, and there pass southwards to the opposite hemisphere, or pole, of the needle, and so complete the circuit. The atmospheric currents of the needle would evidently be disposed to arrange themselves *parallel* to the atmospheric currents of the Earth, as this arrangement offers the least resistance; and this *parallelism* of the needle to the electric currents of the Earth, throughout their entire length and their various positions will be seen, from a very cursory study of the "magnetic curves," to determine both the dip and the declination of the needle.

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* *Humboldt Library*, Vol. IV, p. 20.

According to Werner Siemens, all bodies are filled with such circular currents, and magnetic bodies differ from non-magnetic bodies only inasmuch as the number or quantity of circular currents present in the unit volume is much greater in the first case than in the second.* This might account for the attraction by the magnet of non-magnetized substances, such as soft iron. But perhaps we may find other causes for this attraction when we come to examine the actual molecular mechanism of these phenomena.

145. *Irregular Courses of the Terrestrial Magnetic Lines.*—As the magnetic poles of the Earth do not coincide with the geographic poles, so neither will the magnetic meridians and equator coincide with the geographic meridians and equator. Therefore the course

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***Phil. Mag.*, April, 1885; Jour. Physics, September, 1885.

of the atmospheric electric currents to the South Magnetic Pole would be somewhat anomalous, geographically considered. But whatever direction these electric streams would take, the magnetic needle adjusts itself parallel to them, and points in the direction whence the currents come. As the currents move southwards over the Western Hemisphere, since the Pole towards which they move is situated in the Eastern Hemisphere, they would be deflected both eastwards and westwards, in somewhat diagonal courses towards their destination. East of this place of divergence, the needle would point westwards; west of it, the needle would point eastwards; and in it, the needle would point due north. Similarly, in the Eastern Hemisphere, there would be a confluence of the previously divergent currents, along the line of which the needle would point due north, east of it, eastwards, and west of it, westwards. These lines of divergence and confluence would be the lines of no declination. Their courses are not straight, but veer irregularly eastwards, especially the line in the Eastern Hemisphere. These irregularities in their courses would be probably owing partly to the equatorial protuberance of the Earth, to various irregularities of the land surface, such as mountain ranges and elevated plateaus, and also to the nature and direction of the air-currents through or in which the electric currents move.

The eastern line passes southeastwards through the White Sea, eastern Russia, the Caspian Sea, Persia, the Arabian Sea, then veers eastwards through the Indian Ocean, passing southwards through the western part of Australia to about the Antarctic Circle. A strong corroboration of this material current theory is here met with in the effect which the lofty plateaus and mountain ranges have upon their supposed course. We see how the present eastern line of no declination avoids these obstructions and after passing around them along the low lying regions, veers suddenly eastwards about to its proper position. More than a century ago, the line passed around on the eastern side of these mountains and plateaus; but as it moved gradually westwards, it became divided by the obstruction and passed around it in both directions. There remains even to-day an isolated oval area of western magnets, including the Japan Empire and portions of eastern Asia; which would evidently be owing to the downward sweep of currents from the west which had been deflected upwards into the cirrus regions by the lofty mountain ranges. This isolated region is continually decreasing in size; and as the line moves farther westwards, will eventually disappear. Indeed over all of this region, the deviation of the needle is very slight; so that from the Caspian Sea to the Japan Sea, the needle points almost due north. That is, the direction of the needle is chiefly determined by the electric currents originating in these regions themselves. Thus there seems to be every reason for believing that if the whole of Asia were as low as its northern portion, the line would pursue its normal southeastern course unaccompanied by any peculiarity of loops or isolated ovals, and that the Earth would be about equally divided into two hemispheres of eastern and western magnets.

In offering this view of the deflection of atmospheric electric currents, it is of course not unknown that the height of these currents is held by many eminent observers to be much more elevated than the highest range of mountains on the globe. M. Flögel calculated the heights of several auroræ which appeared in the autumn of 1870, and concluded that only the very lowest parts of the aurora came at all within the limits of the atmosphere; he gave the actual limits as 150 to 500 kilometres. M. Reimaun found a height of from 800 to 900 kilometres for an aurora on October 25, 1870; and Baron Nordenskiöld came to the conclusion that the mean height of the aurora was about 200 kilometres, or more than twenty times the height of the highest mountain on the Earth. The opinion is here ventured, however, that some error may possibly vitiate these calculations. In support of this it may be stated that the more recent observations give much smaller values to the heights of the electric currents. From observations made at Godthaab, by M. Paulsen, and near Cape Farewell, in 1885, by MM. Garde and Eberlin, the heights of the auroræ were found to range from 0.6 to 67.8 kilometres, and from 1.6 to 15.5 kilometres, respectively. And the Swedish International Exhibition, at Spitzbergen found the extremes of these heights to be 0.6 and 29.2 kilometres. M. Paulsen gives accounts of several appearances of auroræ beneath the clouds and the summits of mountains;* and M. Hildebrandsson has seen auroræ in a completely clouded sky.†

But perhaps the most conclusive observation confirmatory of a low elevation for the electric currents is the following: "Arsuk Fiord is in 61° 15′ north latitude. This fiord is 2 miles wide by 25 long, and its shores are steep rocky cliffs, from one to four thousand feet high. Midway of its length, on the south side, lies Ivigtut. At this station the aurora light begins with a development in the west over the north of the fiord, and as it progresses eastward follows the direction of the fiord, sometimes covering its entire length, and having outliers over the smaller arms of the fiord; but ordinarily the western part of this auroral band disappears before the development has extended to the eastern end and new bands of light come again from the western end eastward. The phenomenon is best developed at two hours after sunset, and appears then to be near the Earth's surface, occasionally only 1000 feet above sea-level."[*] In fact, the electric currents of the atmosphere are here observed to have their courses modified by elevated obstructions in a manner precisely similar to that which the irregular course of the eastern line of no declination has led us deductively to expect.

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* In a paper read before the Royal Danish Academy, February, 1889.

† Ibid.

146. *The Diurnal Variation of the Magnetic Needle.*—There are four different kinds of variations of the magnetic needle, the diurnal, the annual, the irregular and the secular. And on the basis of the foregoing views, each of these readily admits of an explanation which seems really beautiful in its simplicity.

We have already noticed how the edges of the Sun's connexion would originate two aerial waves or tides between which would be two aerial troughs or depressions; and also how this is shown to be the actual fact by the barometer. We have here to observe that the diurnal variations conform exactly to these aerial waves and depressions. The barometric maxima are at 8 to 10 A. M. and 8 to 11 P. M., and the minima are about equi-distant from these hours. Now M. Arago, from a careful series of observations of the magnetic elements, deduced the following results: "At about eleven at night the north end of the needle begins to move from west to east, and having reached its greatest easterly excursion at about a quarter past eight in the morning, returns toward the west to attain its greatest westerly excursion at a quarter past one. It then moves again to the east, and having reached its greatest easterly excursion at half-past eight in the evening, returns to the west, and attains its greatest westerly excursion at eleven, as at starting."[*]

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[*] *Zeitschrift der Oesterreichischen Gesellschaft für Meteorologie*, XVII. p. 320; Prof. Cleveland Abbe, *An Account of the Progress in Meteorology in the Year 1883*, p. 70.

A moment ago we noticed how the electric currents are prone to follow the low-lying, and therefore denser, portions of the atmosphere by avoiding the elevated mountain ranges and plateaus of central Asia. We now notice a similar tendency of the electric currents to follow the denser aerial waves or tides, rather than the rarer aerial depressions. At about midnight we are in the middle of the aerial depression; but the morning aerial tide is advancing in the east, into which the electric currents have collected in the far north, and from which they spread out laterally on both sides of the wave on their way southwards. From about midnight to 8 A. M., therefore the needle would point more and more eastward into partial parallelism with these branch currents. At 8 A.M., when near the center of the tide, the eastward deflection is at a maximum. Then the center of the wave passes, and the needle points westwards towards parallelism with the lateral currents issuing from its eastern side. At about midday the needle is again in an aerial depression; but the evening tide is advancing in the east, towards which the needle again turns. Near the center of this wave or at about 8 P. M. there is another maximum of easterly declination. After which the needle again follows the wave westward to about midnight, as before.

[*] *Prof. R. A. Proctor, Humboldt Library of Science*, Vol. II, p. 8.

This remarkably direct evidence in favor of the views here advanced, is also strongly corroborated by the phenomena of aurora and atmospheric electricity. When the aerial tide is over a place, the auroræ are at a maximum. At Cumberland Sound, N. A., the greater number of auroræ always occur at about 6 A. M., and 10 P. M.[*] And the maxima of electricity in the air, as determined from six months observation at the observatory of Lausanne, are approximately at 7 A. M. and 9 P. M.; and the minima are at 3 to 5 P. M. and 3 to 4 A. M.[†] It should be borne in mind that the tidal wave does not occur at different places on the same geographical meridian at the same time except during the equinoxes. Hence arise the slight differences in the hours of the occurrence of auroral and electric maxima at places having the same longitude. When allowance is made for this circumstance, the maxima of the auroræ and atmospheric electricity appear to correspond exactly to the passages of the aerial tidal waves.

In still further confirmation of these views, it is observed that, in accordance with the single diurnal barometric maximum of high latitudes—*i. e.*, the mid-day aerial tide caused by the pulling southwards or northwards of the air particles by the northern or the southern edges of the Sun's connexion, and the mid-night depression corresponding to the absence of this connexion—we have from the observations of aurora at Godthaab, by Professor Kleinschmidt in 1865 to 1880, *a southward movement of the auroral zone during the day and a northward movement during the night.*[‡]

[*] Orray Taft Sherman, *Prof. Pap. U. S. S. S.*, No. XI, p. 199.

[†] Prof. H. Dufour, *Zeitschrift der Oesterreichischen Gesselschaft für Meteorologie*, Vol. XIX, p. 129.

[‡] Prof. Sophus Tromholt, *Om Nordlysets Perioder; Zeitschrift der Oesterreichischen Gesselschaft fur* Meteorologie, Vol. XXIII, p. 306.

Moreover, although it is the chief agent, it is not the Sun alone that affects the terrestrial magnetic and electric elements; for Sabine has discovered that the Moon also (as by the new theory we should naturally expect, and in about the ratio which that theory assigns) has a distinctly traceable and similar connection with them; the lunar effects in the lunar day being the analogues of the solar effects in the solar day.*

147. *The Annual Variation of the Magnetic Needle.*—The annual variation of the magnetic elements is chiefly a modification of the diurnal variation. Thus in the summer season of the Northern Hemisphere the daily variation is about twice as great as in the winter. This is evidently accounted for by the solar connexion sweeping more directly over this hemisphere at this time. The maximum tidal effect of the connexion is at the edges; but it is the aerial tides of the east and the west edges that would chiefly carry the electric currents, because the directions of the electric currents and these edges approximately coincide. In our summer these edges of the solar connexion are chiefly in the Northern Hemisphere, and therefore we have a maximum diurnal variation. In our winter these edges are chiefly in the Southern Hemisphere, and therefore the maximum diurnal variation is then in that region, and we have our minimum diurnal variation.

It has already been observed (Art.38) that there are maxima and minima of auroræ corresponding to the maxima and minima of sun spots and of the planetary factor of the connexion-variations upon the Earth. But as the sidereal factor of the connexion-variations upon

*Prof. R. A. Proctor, *Humboldt Library of Science*, Vol. II, p. 10.

the Earth is shown, by the phenomena of atmospheric precipitation, to predominate over all other factors, it would seem that there should also be a maximum and minimum of atmospheric electricity corresponding to the variations of this factor also; that is, a maximum some time in the first half of the year; and a minimum in the last half. And this appears to conform precisely with the facts so far as they are known. Thus it has been found by P. F. Denza from twelve years' observations—six times daily—at Moncalieri that "the daily variations show themselves clearly in the winter and summer, having two maxima after sunset and sunrise. The yearly variations attain their maxima at the end of February, the minima at the end of September." * But while the observations thus generally accord with the theory, it should be borne in mind that many causes (some of which are known and many of which are probably unknown) would modify the actual maxima and minima of atmospheric electricity; and moreover our system of observation of the phenomena involved is, to say the least, very incomplete.

148. *The Irregular Variations of the Magnetic Needle.*—The irregular variations of the magnetic elements are such as break in suddenly, and often with great violence, upon the quiet regularity of the others. There is scarcely a doubt, even among the ablest exponents of the present views upon the subject, that many, if not all, of these irregular variations are owing to some disturbances taking place upon the Sun. How such disturbances could be transmitted, they frankly admit their inability rationally to explain. But they have observed the disturbances take place upon the Sun; they have noticed that these disturbances were

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* Prof. Cleveland Abbe, *An Account of Progress in Meteorology in 1879-81*, p. 88.

almost immediately followed by violent disturbances of the Earth's magnetic and electric elements; and therefore the connection of the two disturbances was undeniable. We need not here particularize such instances as they are well-known generally. Their explanation seems sufficiently simple. It is, as just stated, known from observation that tremendous convulsions occur upon the Sun. Enormous masses of gas and flame are hurled with frightful energy upwards into its outer atmosphere. If such eruptions occur upon the side of the Sun next to the Earth, the disturbance is at once communicated to the connexion between the two bodies, by the extremely elastic medium of which it is conveyed as an enormous wave or pulse towards our planet. This pulse is transmitted to the earth-currents, and by the earth-currents northwards to the atmospheric currents, where it becomes manifest as a splendid aurora, and the intensity and momentum of which, drives the aerial currents, and consequently the magnetic needle, from their ordinary courses, often to the comparatively great extent of several degrees. Thus would the disturbance originating on the Sun be transmitted to the Earth's atmosphere. "Nay," in the words of Prof. Proctor, which appear to be at least half the truth, "it is even probable that every flicker and corruscation of our auroral displays correspond with similar manifestations upon every planet which travels round the Sun." It may not be the *amount* of connective fluid transmitted to the Earth by this solar wave that wholly causes the terrestrial perturbation. The more probable causes are, the violent energy of its transmittal, its simultaneity over the entire hemisphere next to the Sun, and the convergence of the rays of the solar connexion as they approach the Earth. But even its amount is far from insignificant, as the solar eruption sometimes continues for hours, and even days, shooting upwards among, and in all probability displacing, the planetary connexions.

149. *The Secular Variation of the Magnetic Needle.*

(*a*) *The Earliest Observations.*—The earliest observations of the secular variation are probably those taken in Paris. At that city, about the year 1541, the needle pointed 7° east; and about 1580, 11½° east, being the maximum eastern declination. The needle then began to move westwards, and about 1663 had returned to the meridian. The declination then became westerly, and continued to increase, until, about 1814, it attained its maximum, 22° 34′ west of north. It is now gradually moving eastwards. In London, the declination of the needle, about the year 1576, was 15° 11′ east; about 1657, due north; about 1700, 9° 40′ west; about 1778, 22° 11′ west; about 1819, nearly 25° west; and about 1843, 23° 8′, west. At Boston, the declination about 1708 was 9° west; about 1807, 6° 5′ west; and about 1840, 9° 18′ west.

(*b*) *Explanations of the Observations at London and Paris.*—In explanation of these various positions of the magnetic needle, it may be well to reconsider some things already noticed. The two lines of no declination are about on opposite sides of the Earth. The one now in the Western Hemisphere is theoretically the line of divergence of the electric currents; and that in the Eastern Hemisphere, the line of confluence of these currents. And, it being granted that the needle points in the direction whence the electric current comes, it follows that the maximum eastern or western declination at any place, will be, other things equal, when it is midway between the two lines of no declination; western, if east of the line of divergence, eastern if west of it. The motion of the electric currents is principally southwards, and at the two lines of no declination is wholly so. The divergence close to the western line would be slight, but farther away from it the angle would increase; but beyond a certain limit the angle would decrease, as the opposite line of convergence was approached.

Now, according to this theory, Paris, about the year 1580, must have been nearly midway between the two lines, and west of the line of divergence, as the declination was easterly. But the line of divergence was slowly advancing westwards over the Earth (the cause of which will shortly be discussed), and the divergent angle of the currents consequently diminishing, the needle would begin to move westwards, and so continue. After eighty-three years, or about 1663, the line of divergence would have advanced westwards to the city, and the needle pointed due north. Still, after this, the needle would keep moving westwards into parallelism with the eastern divergent currents, until some 151 years after the passage of the line, or about 1814, the city was again nearly midway between the two lines, but east of the line of divergence. After this, the needle would begin to move east, in obedience to the gradually diminishing angle of convergence of the currents as the line of confluence advanced westwards. This eastern movement still continues to the present day, the line of confluence being yet advanced only as far as the Caspian Sea.

The magnetic history of London is similar in about all respects, save the dates. This city is about 3° north and 2° west of Paris, and what is chiefly remarkable in the magnetic history of the two cities is that the divergent line of no declination advanced to London about 6 years before it arrived at Paris. In London the needle pointed due north, about in 1657; in Paris it did not point due north till about 1663. But here again we see the theoretical effect of mountain ranges in deflecting the electric currents. Over the lowlands of Russia and Germany the magnetic line advanced at an approximately uniform rate, but farther south the advance of the line was delayed by the apparent obstruction of the European Alps and the elevated regions surrounding them, so that it probably formed a loop extending eastwards around these regions, as about a century later the opposite line formed a loop around the Asiatic ranges and plateaus. Thus it may have been that the magnetic meridian appeared at London before it appeared at Paris, southeast of London. Paris would have been simply inside the loop surrounding High Europe, and London just outside of it on the north.

In further support of the view that this delay at Paris was a merely accidental circumstance, we further observe that the maximum western declination occurred at that city about the year 1814, while at London, on the contrary, it occurred about the year 1819, or just about at the time it was normally due. In the former year, at Paris, the effect of the obstruction would have been to check the western movement of the line (and therefore the variation of the magnetic needle) to a later time than if the obstruction had not interfered, while in the latter year, after the line did overcome the obstruction, its progress was comparatively rapid with respect to that locality, and fully made up for its previous delay; whereas London, being further removed from the obstruction, would have a more uniform variation of the magnetic lines.

(c) *The Southeastern Direction of the Lines of no Declination.*—Another remarkable peculiarity to be noticed is the southeastern direction in which the lines of no declination extend, the southern portion lagging behind the northern. This may be attributed, partly at least, to the tenacity with which the electric currents apparently cling to the land surface in preference to wide and deep bodies of water. In confirmation of this view, it may be mentioned that the intensity of the magnetic elements is much greater over the land, and especially the island surface than over the ocean surface.[*]

(d) *Explanations of the Observations at Boston.*—About the year 1657, the needle pointed due north at London as we have already noticed. But in what direction the north end of the line of no declination extended from London at that time we appear to have no record. About fifty-one years afterwards, however, or in 1708, the declination at Boston is recorded to have been nine degrees west. This evidently goes to show, according to this theory, that in 1657, or shortly thereafter, the line of no declination extended almost due west from Southern Europe across the Atlantic Ocean, passing northwards to the west of Boston and perhaps recurving again northeastwards parallel to the northeastern coast. There is nothing particularly remarkable in this; indeed an instance very similar to it occurs in the Indian Ocean at the present day. But what seems strange is that, for the next hundred years, or up to 1807, the western declination at Boston *continually decreased;* whereas, according to analogy and theoretical deduction it ought to have *continually increased.*

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[*] See paper "*On Local Magnetic Disturbance in Islands Situated far from a Continent*, by Staff-Commander E. W. Creak, R. N., F. R. S.; read before the Royal Society, January 28, 1886, and abstracted in *Nature* XXXIII, 404.

Of this curious phenomenon, the following explanation is suggested by the new theory. The western extension from Europe of the divergent line of no declination in the latter part of the 17th century, took place probably in a comparatively short time. The southern end of the line yet, and for many succeeding years, clung to Southwestern Europe and Africa. Now this diagonal southeastern extension of the line would have a tendency to reduce the eastern declination and increase the western declination upon the western and eastern sides respectively of the line. Thus we observe that at both London and Paris, about the year 1580, the maximum eastern declination was only about half what the maximum western declination was about 240 years later at the same places, while evidently, if the line of no declination extended north and south, the eastern declination would be very approximately equal to the western. Similarly at Boston, in 1708 the western declination was greater than it would be if the magnetic lines were parallel to the geographic meridian, instead of being at a comparatively great angle to it. But about this time the southern end of the divergent line freed itself from the hold of the Eastern Continent and was making relatively rapid strides across the Southern Atlantic (which has few islands) to the Western Continent. This rapid western movement of the south end of the line, while the north end moved at a much slower rate, tended to straighten the whole line, and therefore to diminish the western declination at Boston and other places north and east of the line in its anomalous position. So that in the period from 1708 to 1807, during which the straightening movement took place, the declination was reduced at these places nearly 3°, or from 9° west to 6° 5′ west. After the line had touched South America, the western secular movement slackened to about a parity throughout its whole length, the western declination at Boston again increased owing to the western movement of the whole divergent line, and so continues at the present time.

(*e*) *Explanation of the Secular Variation.*—It now only remains to inquire into the cause of this continual western movement of the magnetic meridians and poles. And, without futher preface, the simple answer is—The *eastern* rotation of the Earth on its axis. It has already been noticed that the connective fluid set free in the earth-currents tended to escape *from* the plane of the ecliptic where the fluid is most dense; and this movement away from the *ecliptic plane* would, owing to the inclination of the Earth's axis, be towards some point of the polar circles, which would be a magnetic pole. The electric currents, becoming once established in certain routes in the Earth's crust, would have a tendency to follow such routes more readily thereafter; so that, although the rotation of the Earth carries the magnetic axis out of its natural position of perpendicularity to the ecliptic plane, the resistance offered to this wrenching of the axis is comparatively small, compared to that offered by the Earth's crust to the continual establishment of new momentary routes perpendicular to the ecliptic; so that the magnetic axis remains practically permanent in any place, and is thus rotated eastwards around the geographic axis once in every 24 hours.

But although the resistance offered to the wrenching of the magnetic axis out of its vertical position with respect to the ecliptic, is comparatively small, yet it is constantly maintained (which the opposing resistance is not); and although its effect is practically inappreciable in one rotation, yet in the course of a year it gradually accumulates so as to become quite perceptible. Taking the magnetic axis (or the general electric earth-current) in its vertical position to the ecliptic plane, and following it eastwards around the Earth's axis of rotation, we observe that, during the first half of the rotation, the tendency of the former would be to return westwards to the vertical position; but, during the last half of the rotation, the tendency of the magnetic axis to adjust itself to the vertical would urge it eastwards, as the nearest way to that position then lies in this direction. But the tendencies of the magnetic axis in these opposite directions do not balance each other for the reason that the Earth's rotation favors the one tendency and opposes the other. A much greater and more effective force or pressure is manifestly exerted by the electric fluid when tending to regain its vertical position to the ecliptic diagonally backwards *against* the Earth's rotation, than when tending to gain that position diagonally forwards *with* the Earth's rotation; just in the same manner that a much greater pressure is exerted by the current of a river upon a boat moving diagonally *against* it, than upon a boat moving diagonally *with* it. And this greater pressure of the electric fluid of the crust against the Earth's rotation exists, not for half the time of a rotation only, but is constantly maintained during the whole rotation. For the currents are continually flowing northwards upon *all* sides of the Earth, and therefore there is a balance of pressure exerted against the Earth's rotation for every moment.

It does not apply here that the electric fluid flowing northwards from the Equator and partaking of the swifter rotational motion at that place, would tend to preserve it as it moved northwards and thus tend to move eastwards instead of westwards,—first, because the magnetic fluid is supposed to issue chiefly from the neighborhood of the South Magnetic Pole, rather than from the Equator; and second, because, as we shall shortly find, the electric flow is incomparably more rapid than the Earth's rotational motion. The explanation of the terrestrial secular variation, then, is simply that this continual balance of pressure of the magnetic Earth currents westwards over the Earth, slowly and gradually changes their course (and therefore that of the magnetic axis) towards this direction. Other causes may contribute; but evidently this is the primary cause. The variation does not take place at an equal rate all over the Earth, or even at neighboring localities; but lags behind in some areas and shoots forwards with comparative rapidity in others. The magnetic meridians and equators are invariably distorted and twisted into unsymmetrical forms;—all of which clearly refers to an unevenly resisting crust medium through which the electric currents are slowly effecting a change of their courses.

150. *Corroborative Evidences.*—In conclusion of this chapter, we cannot do better, perhaps, than to notice a few observations out of hundreds of similar ones that have been made by other inquirers in this department of nature, which seem throughly to corroborate the general theory of terrestrial magnetism here offered.

On the morning of March 30, 1886, a violent earth-current storm occurred in London, stopping all telegraphic work. During the same time, strong earth-currents were reported on the Mediterranean, Bombay and Madras, the Madras, and Penang, and the Java, China, and Japan, cables; causing all work over them to be stopped. In the evening, brilliant auroræ were observed at Donegal and Kingstown in Ireland, at Königsberg in Prussia, and no doubt at many other places from which no reports were made.[*] This evidently goes to show that there is an intimate connection between the earth-currents and the auroræ, as the theory postulates.

In an article on terrestrial magnetism in the 9th edition of the Encyclopedia Britannica, Prof. Balfour Stewart endeavors to show two things: "(1.) That of all the various hypotheses which have been started with the view of explaining the solar diurnal inequalities of terrestial magnetism, the most probable is that, which considers these inequalities to be caused by electric currents in the upper regions of the earth's atmosphere. (2.) That in the neighborhood of the North Magnetic Pole (judging from observations discussed by Sabine) such currents have in all probability horizontal components flowing in from all sides towards that pole, so that on one side of the pole this component will have a direction the reverse to that which it has on the opposite side of the pole." This also is just what the new theory teaches. The same scientist, in a paper "On the Cause of Solar Diurnal Variations of Terrestrial Magnetism" (read before the London Physical Society, April 10, 1886), after reviewing various other theories and hypotheses, says: "We seem, therefore, compelled

[*] *The Electrician*, April 2, and August 6, 1886; *Nature*, XXXIV, 408.

to seek for the cause of the variations in the upper atmospheric regions, and we can not imagine such a cause to exist in any other form than that of a system of electric currents. That currents may, and actually do, exist at great heights is shown by the aurora, which is unquestionably an electric current, and manifests a close connection with the phenomena of terrestrial magnetism."*

M. Faye, before the Paris Academy of Sciences, April 19, 1886, "deals with the important series of diagrams appended by the Astronomer-Royal to the volume of Greenwich Observations for 1884, embodying the diurnal variations in horizontal direction and intensity of the terrestial magnetic force for the thirty-six years ending in 1876 inclusive. As a general result it would appear that the magnetic curves, as exhibited in the 430 diagrams of Sir G. B. Airy's series, contract and expand periodically in direct agreement with the greater or less prevalence of the solar spots, and also with great regularity according to the seasons, the summer curves being invariably far greater than those of winter."†

Dr. Weinstein, before the Meteorological Society of Berlin, March 2, 1886, spoke on the subject of earth-currents, as follows:—"The earth-current showed a perfectly regular daily variation. In the night the earth-current is slight; from 8 o'clock in the morning it regularly increases, attains its maximum precisely at 12 noon, thence sinks rapidly till 4 p. m., whence it continues uniformly weak, not to revive till the following morning. A course precisely analogous to that of the earth-current was manifested by the earth's magnetism, the connection of which with the electricity of the earth attracted attention from the very beginning, when disturbances made themselves observable. To demonstrate with perfect precision the coincidence of the two phenomena it was necessary to take for the purpose of comparison not a single earth-magnetic element, but the earth's total magnetism. The earth's electricity and the earth's magnetism showed, moreover, in their regular daily course, their affinity, by the simultaneity with which their disturbances occurred. This simultaneity was so precise that in one case the distance between Berlin and Wilhelmshaven could be determined from the time when the disturbance of the earth's current made itself felt in Berlin, and the time when the magnetic disturbance occurred in Wilhelmshaven. This simultaneity of disturbances at distant points of the earth pointed to a cosmical cause. Thus, in August last year, at the very time when in Paris the emergence of an altogether unusual solar protuberance was observed, a magnetic disturbance was registered in Petersburg, and a disturbance of the earth's current in Berlin. The earth's current and the earth's magnetism showed further in common the periods of eleven years which coincided with those of the solar spots. In respect of the earth's current, this period could not indeed be demonstrated to a certainty, seeing that the regular observations made respecting it were yet of too recent date; but the regular course of the oscillations warranted the conclusion of a like period being drawn. . . . . . With reference to the question which phenomenon was the primary, the earth's current or the earth's magnetism opposite views were entertained."*

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* *Nature*, XXXIII, p. 620. † *Nature*, XXXIII, 622.

In a subsequent communication to the same society, April 6, respecting the disturbances which had occurred

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* *Nature* XXXIII, 624.

January 9, and March 30, 1886, Dr. Weinstein states "that on March 30, the disturbances were so great that in the course of the forenoon telegraphic communication in Germany was stopped. Even with currents of 60 Daniells no signs could be forwarded by the telegraph wires. The magnetic elements in Wilhelmshaven showed great simultaneous disturbances, and from the direction of these magnetic disturbances it was inferred that the disturbance of the earth's electricity were the primary, the oscillations of the earth's magnetism the secondary."* This precisely agrees with the theory; the incoming disturbing wave of connective fluid first appearing in the electric currents of the crust, and subsequently affecting the magnetic elements, just as we have theoretically deduced.

From autographic records of the magnetic storms of 1880, August 11–14, at Pavlosk, Kew, Zikawei and Melbourne, Prof. H. Wild concludes that "the disturbance of all three elements, declination and horizontal and vertical intensity, began and ended simultaneously . . . The magnitude of the perturbation for each element, especially the intensity, and for each day, shows a diurnal period closely coinciding with normal daily variations." The same scientist from magnetograph records of the magnetic weather of January 30—February 1, 1881, at eleven places in America, Europe, China, India and Australia, finds that "the perturbations began everywhere simultaneously, so far as the time scales enabled the moments to be determined. . . . . The times of occurrence of maxima and minima, and the amplitudes, especially of the variations in declination, correspond very closely to the distance of the stations from the auroral circle surrounding the north magnetic pole, as lately defined by Baron Nordenskiold." * Also from observation of earth-currents made upon buried telegraph cables in the neighborhood of the observatory at Pavlosk up to September 1883, he draws the following conclusions:—

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* *Nature*, XXXIV, 24.

"The earth current appears not like a current of nearly uniform intensity, but as alternating stronger and weaker currents."

"Only by taking the mean of the twenty-four term days during the year do we find traces of slight diurnal change whose amplitude corresponds nearly to 0.0008 volt. The diurnal change of the earth current is therefore not the cause of the diurnal change in the magnetic elements."

"As soon as the earth currents in both lines become strong, the magnetic instruments deviate from their ordinary positions, and these perturbations increase with the strength of the earth currents, but not in any regular proportion."

"The changes in the south-to-north line preceded by about five minutes the changes in variation of declination so that the earth current would appear as the primary cause. He concludes that the earth currents are the primary cause of many perturbations, but not the cause of the periodic variations in the magnetic elements." †

Now all of this is very obviously in perfect harmony with the connective theory. The simultaneity of the disturbances of the magnetic elements over the whole Earth points unmistakably to a cosmical cause of them. The small time-interval of five minutes

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* Prof. Cleveland Abbe, *An Account of the Progress in Meteorology in 1883*, pp. 66-68.

† Prof. Cleveland Abbe, *An Account of the Progress in Meteorology in the year 1884*, pp. 111-112.

between the appearance of the disturbance in the earth-current at Pavlosk and its reappearance in the aerial currents as affecting the magnetic needle, indicates the extreme velocity of the terrestrial electric currents; and the correspondence of the times of maxima and minima of the variations of the magnetic elements at various places to the distances of these places respectively from the north auroral circle, indicates clearly the course which the electric currents take and their mode of distribution. We read also that the magnitude of the magnetic perturbation shows a diurnal period coinciding with the diurnal barometric variations. This shows that a proportionally great amount of the disturbing fluid (as well as of the ordinary currents) appearing at the polar regions is gathered into the aerial tides theoretically shown to account for the diurnal variations. And still another discovery by Professor Wild that furnishes a very strong confirmation of the theory, is that there is no appreciable variation of the earth-currents corresponding to the diurnal or other periodic changes in the magnetic elements. This certainly goes far to prove that the atmospheric tides caused upon the Earth by the solar-connexion is the sole cause of these changes, as the theory predicates. That there is apparently no regular proportion between the irregular perturbations of the earth-currents and the immediately following disturbances of the magnetic elements, may very reasonably arise from the infinitesimalness of the observed portions of these currents, the great bulk of which is probably deep-seated in the Earth's crust.

It may here be remarked also that there appears to be a strong connection between the electric currents, cirrus clouds and precipitation. Change of weather almost invariably accompanies unusually brilliant auroræ. The electric tension of the air is also profoundly modified by precipitation; and lightning can only occur during, or in connection with, rain. We are hardly prepared at this stage of the inquiry to say whether the electric fluid itself is directly converted into the precipitated water, or water-vapor, or merely accompanies the fluid which, in a lightning flash, is so converted. That the lightning flash is itself a manifestation of connective substance in some form or transformation, and even disturbs the magnetic needle, there is, however, no doubt. We may close the chapter with the following suggestive extract regarding the connection of thunderstorms, auroræ and solar disturbances:—

"As the result of the extended series of observations described, it has been found in general that whenever groups of faculæ, with or without dark spots, are appearing by rotation or are bursting forth upon the earthward side of the sun, there is an immediate increase in thunderstorms in the lower latitudes, and probably auroras in the higher latitudes. If, however, the aurora becomes visible near the equator at such times, there is an immediate, though, perhaps, temporary, decrease in thunderstorms, as though the aurora had taken their place. In short, the aurora and thunderstorms appear to have a common origin, and in certain localities, at least, a reciprocal relation to each other.

"The relation between the various phenomena is such, that if an increase of thunder-storms or auroras is noted, faculæ coming into view by rotation or bursting forth elsewhere upon the sun may be looked for with confidence. On the other hand the appearance upon the sun of bright faculæ betokens an immediate increase in the electrical phenomena attending the storms which may be prevailing at the time anywhere on the face of the earth, unless an aurora should intervene, as has already been noted.

"In general the disturbed solar and terrestrial conditions increase or diminish in like ratio. The curious fact has been noted, however, that a single disturbance occupying the sun's disc alone seems to have a more marked effect than a succession of such disturbances as though variability of tension were most concerned in the production of the phenomena in question." *

CHAPTER IX.

GEOLOGICAL CLIMATIC CHANGES.

151. *Geological Periods.*—Having now examined the general phenomena of cosmical evolution and gravitation, planetary light and heat, aerial and oceanic tides, and terrestrial magnetism, in their relation to the new theory, and invariably finding a simple and apparently unquestionable harmony of that theory with the facts—let us now turn into a different department of scientific inquiry and see if the same harmony is there manifested also. Having tested the theory by the various manifestations above and upon the Earth's surface, let us now proceed to test it by the manifestations beneath the Earth's surface, or the testimony of the Earth's crust itself. This crust upon which we

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* M. A. Veeder, *The Electrical World*, Vol. X, No. 9; *Monthly Weather Review* (of the U. S. Signal Service), July, 1887, p. 206. An article on the same subject, by Henry C. Maine, also appeared in *Frank Leslie's Illustrated Newspaper* of August 31st, 1889.

have our being, has certainly been subjected to vast changes both of form and surrounding conditions; and if the new theory be in the main the true one, it will even yet be subjected to changes compared with which the past changes, the evidences of which the crust affords, are utterly insignificant. However, it is the records of these past changes that we are here to examine; and though perhaps they are relatively insignificant, we shall nevertheless find them vast enough for the consideration of our puny human faculties.

The time since the appearance of the human race upon the Earth is apparently but a moment of the Earth's history. There is some evidence that man existed shortly prior to the great Ice Age, but the highest scientific authorities are of the opinion that the earliest traces of paleolithic man is to be found in the river drifts deposited after the vast glaciers began to melt away. Now, the duration of the great Ice Age is said to be double that of the period since, and yet the Ice Age and the period since together are supposed to be on the most probable basis, but a fraction of one per cent. of the period since the formation of the present crust upon the Earth.

152. *The Age of Ice.*—For hundreds of thousands of years, then, probably before the first appearance of man, vast sheets of ice covered the temperate regions which we now inhabit, and perpetual winter reigned half way to the Equator. But still prior to this, for a far longer period, the climate of the same regions was extremely torrid, and perpetual summer reigned as far north as the Pole. Of these vast changes in the Earth's climate in the past, there is no question whatever among scientific men. The evidence is abundant and unmistakable, and carries conviction at once to the mind of the

student of nature. But if we ask the scientist how these changes of climate came about, we practically receive no answer. He does not know. He has, or rather he had, theories regarding these climatic changes, but they are all untenable, and so obviously so that they are now about all practically rejected and laid aside. The late Mr. Searles V. Wood, in a summary of the possible causes of the succession of cold and warm climates, enumerates no less than seven different theories, which have met with more or less acceptance. And Sir J. William Dawson, in his inaugural address at the fifty-sixth annual meeting of the British Association, justly exclaims that "nearly every cause available in the heavens and the earth has been invoked to account for these astounding facts."

The theory of Dr. James Croll, as elaborated in his works "Climate and Time," "Climate and Cosmology," etc., was probably the ablest as well as the most widely accepted. But after a critical examination of it by Dr. Woeikof,* not to mention former criticisms by Simon Newcomb and others, there remains little else than a series of erroneous assumptions. In the words of J. Norman Lockyer—"His whole system of estimating temperature breaks down when seriously tested, the errors being enormous, in some cases upwards of 100° F., or greater than the difference of annual temperature between the equator and the North Pole. His hypotheses, although brilliant and fascinating, can not be accepted, the main points on which they rest being opposed to the most certain teachings of meteorology, and the whole fabric, in its explanation of glaciation and geological climates generally, being entirely fallacious." †

* *American Journal of Science and Art*, March, 1886.

† *Nature*, xxxiv, 46.

53. *The Causes of the Climatic Changes.*—By the new theory, however, the explanation is simple and obvious at a glance. As already intimated some pages back, the Earth, after its transformation from the ring into the spherical form, at once began to contract its volume, and form a crust upon itself, in all respects similar to the solar crust out of which it originated; and also, at the same time, a similar process took place upon the Sun. It appears that this generative process upon the Sun in this case required less time than it did upon the Earth. In other words, the solar crust first matured and brought forth the planet Venus, before the Earth had been delivered of its satellite. The evidence of this solar priority lies in the fact that in the same period during which the Earth gave birth to only one body, the Moon, the Sun gave birth to two bodies, Venus and Mercury. A partial reason at least, for this solar priority would be, that the generative process upon the Sun was supposably somewhat advanced while the Earth-ring was yet extending outwards from its parent, and preparing itself for its aggregation into the planetary form. But no doubt the chief reason of the priority would be the greater centrifugal tendency of the Sun's equatorial surface. In any event, it appears tolerably plain from the new theory that, after the Earth, the next in order of generation of the three bodies subsequently begotten was Venus, then the Moon, and lastly Mercury.

Now it is a corollary reasonably following from this theory, and is practically self-evident, that when the Sun's surface cools and contracts into a solid crust, a much smaller solar heat will be distributed outwards to the planets of the Solar System, than when the Sun's crust is in a gaseous form. From these premises it follows that, at the birth of the Moon, the Sun was tolerably well advanced upon Mercury. By the time the present crust of the Earth was sufficiently formed to support vegetable life, the solar crust would have been in a still more advanced stage, and so would furnish less heat to the Earth than it at present receives. Perhaps this consideration does not with equal probability apply to the Sun's light; which, for aught that we can assign to the contrary, may have remained practically undiminished. At this time of comparative solar frigidity, the light and heat of the Moon, owing to its recent formation might also be relatively great. But the chief source of heat in all probability, would be the Earth itself. It is certain that, at this period, the Earth-crust would be generously warmed over its whole extent by the Earth's internal heat; and with light either from the Sun or the Moon, or from both, the Earth's surface would have been one great hot-bed, and the favorable condition for vegetable growth would be unsurpassed. This would be the Carboniferous Era upon the Earth, in which the vast coal beds were deposited; the comparative thinness of the crust affording relatively frequent opportunities for its upheaval or subsidence. And at the same time the tepid waters would support more gigantic and a greater number of animals than with either a greater or less amount of heat.

But the Earth-heat would gradually diminish at the surface. After hundreds of thousands of years, the temperature would fall upon the land and in the water; the Sun would afford a minimum of heat*; the climate would gradually become frigid; the water would congeal into snow and ice; and excepting probably a strip border-

*Even the Moon if it had any heat-influence at all, would also have become colder.

ing on either side of the Equator, preserved by the remnants of the solar (and possibly also of the lunar) heat, the whole Earth would be one vast sheet of glaciers and ice.

But another change was beginning to dawn upon our planet. When its internal heat had become greatly reduced at the surface, and the Sun also had cooled by radiation so as to furnish but a minimum quantity, the solar crust began to part and the gaseous interior was exposed to view; affording to our world once more the life-restoring heat. This process of crust separation would continue and the heat would increase in intensity until the ring wholly separated from the body of the Sun. This would be the second, or post-glacial, tropical period. After a time the first intensity of the solar heat would wear away, and this gradual diminution would have continued down to the present day; in which, according to the new theory, the solar surface is just in the inceptive stages of its solidification in the process of generating another planet.

By the new theory, then, the sequence of geological climates so far as the present Earth-crust is concerned is as follows: First, very hot, corresponding to the original heat of our globe, the gradual tempering of which produced the magnificent flora and the gigantic fauna of the Coal Measures; second, very cold, corresponding to the cooling and more advanced solidification of the Earth's, the Moon's, and the Sun's surface; third, very warm, corresponding to the separation of the Sun's solidified crust; and fourth, a gradual reduction of the heat of this last period down to the present day. It is scarcely necessary to state that this sequence is precisely similar to that deduced by geologists, from the evidences of the crust itself.

154. *The Supposed Subdivision of the Ice Age.*—There is indeed one apparent discrepancy; which, however, may very possibly be owing wholly to the extraordinary and incorrect causes which the confusion of previous theories compelled scientists to assign for the facts. The view involving this apparent discrepancy is that, very generally received among geologists, which regards the great Ice Age as divided into several portions, separated by inter-glacial periods. This view, if true, would not be absolutely inconsistent with the theory here advanced, as the interruption by various causes of the cooling process upon the Sun can by no means be said to be impossible. But the great probability appears to be that this view is erroneous. Leaving out of consideration the astronomical grounds upon which Dr. Croll and others based the subdivisions of the Ice Age, as having been quite sufficiently criticised by other inquirers, we shall notice one ground for a belief in such subdivision of a very different character.

Archibald Geikie, in his "Geological Sketches"* describes what he thinks is probably the oldest portion of land surface on our globe, in the north-west part of Scotland. A somewhat extensive platform of old gneiss had first been "buried under several thousand feet of red sandstone. . . . . The area was then further submerged until the vast pile of sediment was deposited out of which the Highlands have been formed, that these sedimentary accumulations—how many thousand feet thick we cannot yet tell—were subsequently over the Highland area crumpled and metamorphosed into crystalline schists, and that finally towards the west the ancient platform of gneiss was once more ridged up and gradually bared of its superincumbent load of rock, until now at length some portions of it have been once more laid open to the air. What is strange about the old gneiss platform thus laid bare is the peculiar bossy, hummocky appearance which it presènts, which is not presented by the later formations remaining above it, and which "if they were found in a recent formation, would without hesitation be ascribed to land ice." The overlying formations are marked by parallel striations and bands of rocky terrace, but are far from exhibiting such energy of glacial action as the older gneiss. Moreover the peculiar smooth, bossy character of the latter can be traced *under* the recent formations and under patches of breccia or moraine which have been left standing by recent erosions. From this the inference clearly follows that an earlier period of glaciation existed, which was separated from the recent period of glaciation by the immense interval of time required for the deposition of the red sandstone and overlying schists, and their submergence, crystallization and subsequent elevation.

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* *Humboldt Library of Science*, Vol. IV., p. 101.

Regarding this inference as true, the new theory would yet regard the two periods, however distant, as the inceptive and final stages of one grand period of glaciation. According to this view, the old gueiss was, in the first place, subjected to the action of the glaciers during a comparatively great time in the beginning of the Ice Age; that then it was submerged, water intervening between it and the ice, and had deposited upon it the sandstone and schists by the action of the glaciers and the overlying waters; that subsequently it, with its overlying burden, was upheaved and again subjected to the action of the uninterrupted but diminishing ice, suffering denudation of its overlying deposits in the closing and more moderate period of the Ice Age, and by continued elevation and denudation, itself a second time polished and striated by ice-action.

Also, on the northern Alpine slopes, several continental geologists have been lately engaged in tracing nearly similar marks of the Ice Age. They found tolerably clear evidence that there were two periods of ice-action separated by a long interglacial period. Nineteen instances were found in this region where an older and a younger moraine were separated from one another by a layer that cannot be attributed to glacier action. This layer, they state, is composed in some instances of loam from weathering; in others of "diluvial coal" (which is here understood to be fragments of coal washed by floods from its original bed); in others of river deposits, etc. All these according to the view just stated, must have been deposited by subglacial water-currents either in deep or in shallow water over a sinking area. According to these geologists, the climate of the interglacial period was probably much like it is at the present time. This, by the new theory, would not, of course, be the case. But it is obvious that even with a really intense cold in the middle of the Ice Age, it is not probable that all the water upon the Earth would be solidified into ice. Granting that the diminution of solar heat might have solidified it over most, or even all of the Earth's *surface* down to varying depths; yet below this there would be currents of ordinary temperature of quite sufficient strength to spread alluvium and detritus over its bottom. But even though the waters were all frozen solid during the intensest cold, the deposition of sediment would occur in the more moderate periods before and after such an event.

There is nothing certainly known regarding these alleged interglacial periods. Geologists are by no means agreed either upon their existence or their number. "Opinions differ as to the number of glacial and interglacial epochs, many holding that we have evidence of only two cold stages, and one general interglacial stage. . . . . While some observers are of opinion that there are only two epochs of general glaciation, others, as, for example, M. Tardy, find what they consider to be evidence of several such epochs. Others, again, as M. Falsan, do not believe in the existence of any interglacial stages, although they readily admit that there were great advances and retreats of the ice during the Glacial period." * This last is precisely the view here entertained, except that, instead of advances and retreats of the ice, upheavals and subsidences, various in number in various places, are substituted.

CHAPTER X.

COSMICAL EVOLUTION IN THE FUTURE.

155. *Significance of the Sunspots.*—It is apparent from what has already been observed, that the evolution of the Solar System, according to the new system, is still far from completion—is, in fact, even now going on and will continue to go on. We have noticed when discussing the facts of geology that the Sun is now continually cooling, and the spots which we observe upon its surface we have found grounds for regarding as incipient attempts at solidification of that surface. We

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* Archibald Geikie, *Presidential Address to the Geological Section, British Association, 1889; Nature*, xl., 491.

may here examine these sunspot phenomena more in detail.

Nearly all scientists regard the solar spots as solid, and as cooler than the rest of the solar surface. According to Zollner, the Sun was a white-hot body, and its spots were scoriaceous products of local cooling. Zollner's theory, as elaborated by M. Shulz, sixteen years later, was, that a certain gas, escaping from tremendous pressure in the lower regions of the photosphere into the upper regions of the solar atmosphere, would dilate and cool sufficiently to condense into the liquid and then into the solid state, and thus fall in showers upon the photosphere. When the shower is a light one, a "pore" would be the result; when it is heavy and long-continued, groups of slag-islands would form, around which the photospheric clouds would arrange themselves into the characteristic funnel shape of the penumbra, at the bottom of which is the obscure solid nucleus.

Prof. Balfour Stewart states: "It has been pointed out by the Kew observers that the bottom of a spot is blacker, because it is colder than the general surface, and they have likewise brought forward evidence to show that this diminution of temperature has probably been produced by the down-rush of comparatively cold matter from above, a conclusion which has since been conclusively verified by spectroscopic observations." And again: "We have . . . . in the faculæ the necessary reaction of this, or the uprush of comparatively hot matter from below." And Prof. J. Norman Lockyer says—"We have seen, in fact, that one chief point about the sun is that it is cooled on the outside; that masses of gas going up to tremendous altitudes eventually arrive where the atmosphere is cold and quiet, and where they again take on the solid or liquid form, when they begin to go down again."

These are representative current views from the highest authorities on the subject; and, while they differ somewhat in detail, yet they essentially agree with each other, and with the deductions from the theory here advanced.

156. *The Equatorial Movement of the Sunspots.*—The chief peculiarities of sunspots with respect to motion and locality, which have hitherto remained practically inexplicable, will be seen to find ready and reasonable explanation on the basis of the connective system of evolution. It has been observed that the spots near the sunspot minimum, appear generally about latitude 30° north or south of the solar equator. Here they seem to rotate round with the Sun in a period of some 26½ days (slightly greater south, and slightly less north of the equator.) But, during the succeeding years up to about the next sunspot minimum, the spot-zone gradually approaches towards the equator; where their rotation-period around the Sun's axis is only about 25 days. It may be remarked here, as conceded by nearly all authorities on the subject, that the equatorial regions of the Sun are hotter than the higher latitudes. And another fact which should be borne in mind, is that the sunspots which we ordinarily see are not all the spots which form upon the Sun's surface by the descent of cooled material from above; that, in fact, such spots are *continually* formed upon the *entire solar surface.* Upon this point, Prof. Balfour Stewart may be quoted once more: "What we have on a large scale in the spots and faculæ we have in a small scale all over the Sun's disc. When viewed with a powerful telescope the brightness of

his disc is found to be far from uniform, the whole surface being made up of bright and dark patches existing side by side. This mottled appearance was first noticed by the elder Herschel, who considered the pores, as he termed them, to be small spots—a conclusion which has since been abundantly verified by the spectroscope."*

Now these spots thus forming over the entire surface of the Sun, being solid bodies formed by the descent of cooled material from the upper regions of the solar atmosphere, are obviously denser than the heated ocean in which they float. And as the Sun has a comparatively great velocity of axial rotation, we know from analogy that these denser bodies, having freedom of motion, would tend, owing to the centrifugal force generated by the rotation, to approach the solar equator—just as we have noticed would be the case with the original solar spheroid. But, as, in obedience to this tendency, the incipient crust-fragments move equatorwards, they encounter the greater heat in these lower regions, and are therefore gradually dissolved. At all times, no doubt, there fall by far the greater amount of cooled material in the equatorial regions, and smaller and smaller amounts on equal surfaces as we approach the poles, owing to the decreasing height of the solar atmosphere in these directions. But at the same time the greater heat of the former prevents the aggregation of this cooled material into spots (except when the precipitation is comparatively great in amount, as at sunspot maximum), just as the paucity of the falling material in the polar regions has the same effect. So that, other things equal, the first appearance of the spots would most probably be at the latitudes between the polar and the equatorial regions. This would approximately be the case at the time of sunspot minimum when the planetary connexions are about evenly distributed over the Sun's equatorial surface. But towards the sunspot maximum, the planetary connexions become bunched in certain directions upon the Sun's equatorial surface; the solar atmosphere, ascending in these aggregated connexions, would become elongated outwards from the equator, and consequently would be of still less elevation over the polar regions. Moreover, the ascending vapors also rising higher in the elongated equatorial atmosphere, the showers of cooled matter would descend in still greater profusion upon the equatorial regions; and thus, owing both to the diminished precipitation in the higher latitudes and the increased precipitation in the lower, the spot-zone moves towards the equator between minimum and maximum of sunspots.

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*Nature, XXXIII, 36.

After maximum, however, up to minimum again, we might expect a poleward movement of the spot-zone to the place of beginning. But this return is obviously precluded by the premised circumstances. For as the solar connexions are moving out of conjunction, the regions where they are intermingled and where the elevated density of the connective atmosphere is consequently maintained, becomes smaller and smaller, until it finally disappears at the equator. Thus the wave of spots would continually approach the equator as the connexions moved out of angular coincidence; until finally the previous condition of approximate uniformity of the connective density was restored, and another wave would begin in the intermediate latitudes as before.

157. *The greater Angular Velocity of Sunspots at the Equator.*—Regarding the more rapid equatorial rotation of the spots, the reasonable supposition may be made that the different parts of the Sun, including all but the outward portion of its atmosphere, revolve axially at the same angular rate. This is what happens in our own world, so far as we know; the atmosphere, except in the upper regions, revolving approximately in the same time as the Earth itself: and it seems proper to reason that what happens in our own world happens also in other worlds in analogous cases. From this approximately equal angular velocity of all parts of the Sun in equal times, it follows that the lower and middle regions of the solar atmosphere (in which, probably, most of the ascending vapors are cooled) would revolve with a considerably greater absolute velocity than the proper surface of the Sun, where the spots are formed. Now, as the heated vapors ascend into these atmospheric regions, they gradually acquire the absolute velocity of those regions; and when they become cooled, and fall again to the solar surface in a denser and more compact form, they would take with them a portion, at least, of the increase of absolute velocity thus acquired; so that the spots which they form would really have a greater angular and absolute velocity of rotation than the general surface on which they float. Now, it is clear that the equatorial atmospheric regions of the Sun would have the greatest absolute velocity of rotation, and that this velocity continually diminishes up to the poles of the Sun, where it is nothing. Besides, as the equatorial atmospheric regions extend outwards to a far greater distance from the Sun's center than those in higher latitudes, the absolute velocity of the former would

have a greater ratio to that of the latter than the absolute velocity of the proper equatorial surface would have to that of the proper solar surface of the higher latitudes. Therefore, the cooled matter which falls upon the equatorial regions would not only have a greater absolute velocity, but also a greater angular velocity than that which falls in higher latitudes; and so the period of rotation of the former would be less than of the latter, in accordance with actual observation.

The equatorial movement of the spots would partly counteract this; but this movement is so slow, and the existence of an individual spot, whether large or small, is so short (about ten or twelve days on the average, rarely so high as fifty days), that the effect of this counteraction is relatively insignificant. The same remark also applies to the friction of the solar surface with the spots; which, if the period of existence of individual spots were much greater, would reduce their angular velocity down to that of the supporting solar surface. But the friction of a solid body floating upon the solar surface, whether gaseous or liquid, would probably be so small that, during the brief life of a spot, its effect would be to diminish, rather than to overcome, the extra velocity. It follows, then, from these considerations, that the period of the Sun's rotation would be somewhat greater than those of the spots by which it has hitherto been determined; and that the greater spot-period the most closely approximates to it.

158. *Future Crust-Development and Ring-Formations Upon the Sun.*—Thus, then, does the secular cooling of the Sun proceed; and thus would it, in all probability, continue until, in succeeding ages, and after countless catastrophic interruptions, one solid and con-

tinuous crust would eventually cover the Sun's entire surface. And this crust would expand outwards at the equator, separate into the ring form, and precipitate into a planet with a display of comets and meteorites, just as the first crust did upon the original solar spheroid;—this again to be followed by secular cooling of the new and diminished Sun, by sunspots and succeeding crusts and planets, almost infinitely repeated through the seeming eternity of the future.

159. *Present Crust-Development Upon the Earth.*—On our world we find the development much more advanced than it is upon the Sun; which is scarcely to be wondered at when we recollect that, since the birth of our planet, two crusts have matured upon, and separated from the bosom of the Sun, while the Earth has given birth to just one. But it is only natural that the parent should be more prolific than the offspring in the earlier period of the latter's existence, even though the former did not possess the more powerful rotation and ring-producing energy. The Earth is not yet greatly behind-hand in the matter of progeny; and probably long before the Sun gives birth to another planet, the Earth will be delivered of a second satellite.

160. *Equatorial Expansion of the Earth-Crust.*—The Earth-crust upon which we have our being has long since become cold and firm at the outer surface. It has long since commenced to bulge outwards at the Equator, and this bulging amounts now to thirteen miles from the center all around the Earth. This equatorial expansion, being abstracted chiefly from the polar regions, no doubt leaves these regions with a thinner crust than that of the lower latitudes; which, also, implies a warmer climate there than would otherwise prevail.

We appear to have every reason for believing that this equatorial and expansive movement of the Earth-crust is now taking place, and will continue to do so. It is slow and almost imperceptible; but the evidences of its existence are clear and unmistakable. When we examine the Earth-crust closely, we find that it is in a state of continual tremor; indicating, no doubt, the continual strain to which it is subjected. Prof. G. H. Darwin has investigated these Earth-tremors, and the results at which he arrived are best stated in his own words in the *Fortnightly Review*:—"Within the last fifteen years it has been discovered that the earth's surface is being continually shaken by tremors, so minute as to remain unsuspected without the intervention of the most delicate instruments. In every country where the experiments have been tried these tremors have been detected, and not merely at certain periods, but so incessantly, that there is never a second of perfect rest. The earth may fairly be said to tremble like a jelly. The pioneer in this curious discovery was Father Bertelli. His experiments relate only to Italy, but that which has been found true also of England, France, Egypt, Japan, Brazil, and a solitary island in the south Pacific Ocean, probably holds good generally, and we may feel sure that earth-tremors or 'microseisms' are not confined to countries habitually visited by the grosser sort of earthquakes."

It is probable that as the Earth rotates in the heart of the great connective atmosphere surrounding it, and as the individual connective rays pass from molecule to molecule of the Earth-crust, this alternate tension and relief would occasion vibrations of the parts something like those observed. In support of this view, it has been observed that earthquakes and earth-tremors are more frequent during our winter in both hemispheres, at which time the strain of the solar connexion upon the Earth is most intense. M. Perrey has also shown that there are more earthquakes when the Moon is nearest the Earth, and more when she is on the meridian than in any other position;—all of which is obviously explicable by the undeniably greater strain of the lunar connexion upon the Earth-crust in these positions.

But the strain of the Earth-connexions upon the Earth-crust, would not alone be the cause of the observed tremors. There is also the centrifugal strain caused by the Earth's rotation and which in turn produces a slow and gradual tendency of the crust to move towards the Equator or place of greatest motion. In obedience to this strain the crust is *continually* moving irregularly upwards and downwards and towards the Equator. Quoting again from Prof. Darwin in the same article:—"Rossi has made some interesting experiments with the microphone on microseisms. . . . As long as the microphone is still, nothing is heard; but on the occurrence of the slightest tremor a noise is audible. . . . . The instrument can be made so sensitive, that a fly may be heard to walk near the microphone with a loud tramp. . . . Rossi placed his microphone on the ground, in a cavern sixty feet below the surface, on a lonely part of Rocca di Papa, an extinct volcano not far from Rome, whilst he listened with his telephone at the surface of the earth. He then heard the most extraordinary noises, which, as he says, revealed 'natural telluric phenomena.' The sounds he describes as 'roarings, explosions occurring isolated or in volleys, and metallic or bell-like sounds.' They all occurred mixed together, and rose and fell in intensity at irregular intervals. He found it impossible by any artificial disturbance to a microphone to produce the greater number of these noises. The microphone is especially sensitive to vertical movements of the soil, whereas the tronometer fails to reveal them. Nevertheless, there was more or less concordance between the agitations of the two instruments. In order, then, to determine the noises corresponding to various oscillations, he transported his microphone to Palmieri's Vesuvian observatory, where mild earthquakes are almost incessant; here he discovered that each class of shocks had its characteristic noise. The vertical shocks gave the volleys of musketry and the undulatory shocks gave the roarings."

And again: "Astronomers are much troubled by slight changes in the level of the piers of their instruments, and they meet this inconvenience by continually reading their levels and correcting their results accordingly. Of course they also take average results. These troublesome changes are probably earth tremors, with so slow a motion to and fro that the term tremor becomes inappropriate. This kind of change has been called a displacement of the vertical, since a plummet moves relatively to the ground. Thus we found at Cambridge that as the pendulum danced it slowly drifted in one direction or the other. There was a fairly regular daily oscillation, but the pendulum would sometimes reverse its expected course, for a few minutes, or for an hour. During the whole time that we were observing, the mean position of the pendulum for the day slowly shifted in one direction; but even after a voyage of six weeks the total change was still excessively small. How far this was a purely local effect, and how far general, we had no means of determining.

"This is a subject which M. d'Abbadie, of the French Institute, has made especially his own. Notwithstanding his systematic observations, carried on during many years in an observatory near the Bay of Biscay, on the French side of the Spanish frontier, hardly anything has been made out as to the laws governing displacements of the vertical. He has, however, been able to show that there is a tendency for deflection of the vertical toward the sea at high tide, but this deflection is frequently masked by other simultaneous changes of unexplained origin."

Also, it has long been known that earthquakes are preceded by tremors leading by a gradual crescendo to the destructive shocks, these shocks being, by this theory at least, partly due to the sudden adjustment of parts of the crust to accumulated centrifugal stresses. According to this view, then, the displacement of the Earth-crust should, on the whole, be in a direction towards the Equator; and, as a matter of fact, this appears to be borne out by actual observation. "An examination of observations made at a number of Northern observatories during the past seventy-five years—Königsberg, Milan, Naples, Paris, Pulkowa and Washington—appears to confirm the existence of such changes. At Pulkowa, which furnishes the most careful series of observations, a diminution of the latitude of 0″.23, equivalent to about 23 feet, is indicated between the years 1843 and 1872; but in all these cases the variations are small, and we must be extremely cautious in ascribing them to actual changes of latitude."[*] It does not seem, however, that 23 feet in the time stated is so very small a movement of the Earth-crust towards the Equator after all; and although we certainly ought to be cautious of accepting it as a fact, it would just as certainly be very imprudent to regard the evidence of our own eyes with undue suspicion, because its acceptance would so profoundly modify the existing doctrines. Speaking of this subject, Prof. C. A. Young mentions incidentally —"As regards the earth's form and dimensions, it has become quite certain that Bessel's ellipticity ($\frac{1}{300}$) is too small. Clark's value of $\frac{1}{294}$ is now admitted and employed on the U. S. Coast Survey with a decided improvement of accordance. A slightly larger value even is suggested by the most recent pendulum observations, and $\frac{1}{292}$ is now adopted in Europe. . . . At the same time it is becoming increasingly evident that very little is now to be gained by endeavoring to find a spheroid fitting the Earth's actual form more closely. It will be best simply to adopt some standard (say that of Clarke, but it makes very little difference what), and to investigate hereafter the local deviations from it. These deviations seem to be larger and more extensive than used to be supposed, the station errors in latitude and longitude being at least quantities of the same order as the variations of elevation." *

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[*] William C. Winlock, *An Account of the Progress in Astronomy in the Year 1885*, p. 61.

We have here, then, very strong confirmatory evidence of our theoretic deductions. The observations are obviously not as complete and decisive as they would be if guided by a true principle or system; but, lacking such guiding principle, they certainly seem as decisive as could reasonably be expected, in view of the extreme minuteness of the phenomena to be observed.

161. *Ring-Projection of the Earth-Crust.*—It appears, therefore, both from our theoretic deductions and from actual observation, that our world is at the

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* *Nature*, XXXV., 67.

present time continually changing its form and its dimensions; continually, but with extreme slowness, propelling its surface crust towards the Equator, thus diminishing its polar and increasing its equatorial diameter. Have we any grounds for believing that this change is to have a period and will eventually cease? On the contrary, the new system indicates that the change will continue into the future, and that, instead of ceasing, it will gradually increase in energy. For, owing to the increased equatorial diameter, the absolute rotatory velocity of the equatorial regions will be increased on the basis of the observed equal angular rate of rotation of all terrestrial parts, and this increased absolute velocity of the equatorial regions will in turn increase the centrifugal tendency by which the expansion of the equatorial diameter takes place. By this system of evolution, then, we have no alternative but to regard the changes now taking place in the Earth-crust as mere steps in the general cosmical evolution, subsequent steps of which will be the projection of the crust into an Earth-ring, and the disruption of this ring into a second terrestrial satellite.

162. *The Primary Connexion of the Earth-Crust.*—We may, perhaps, profitably glance at the various steps of this process of change which will take place in our Earth-crust, even though at the expense of some repetition. Premising, as in the case of the original solar spheroid, that atoms are connected with contiguous atoms, and that molecules formed from such atoms will also be connected with similar contiguous molecules by bonds stronger and more complex than those of atoms, as the molecules themselves are more complex than the atoms, we can comprehend how the particles of the initial fragments of crust (the *Earth-spots,* as

they may be termed) would firmly cohere, and how the connexions between such crust fragments and the heated vapor underneath (which hold the two together) would diminish in complexity and strength from the fragments downwards into the vapor. And after the crust became continuous, as it is at present, we can conceive that its particles are still held together by their molecular connexions, as well as to the vapor underneath the crust by the graduated connexions with that vapor. As each particle of the crust originally lay upon the bosom of the vapor, and so had its independent connexion with it, and as the coalescence of particles reasonably involves also the coalescence of the connexions of these particles with the vapor, it follows that however piled up and aggregated the crust particles eventually become, each would still have substantially its own original connexion with the vapor, although really the individual connexions of a mass of particles may be joined into a complex bond, as the mass itself is a complex body of molecules. So that between the present Earth-crust and the internal vapor we may posit the existence of a bond of union which is equal to the aggregated bonds of all the individual particles of the entire crust. As the crust moves equatorially, it would evidently be accompanied by a similar movement of the bond; and when the crust separates from the Earth in the ring form, the undiminished bond would still unite the ring with the Earth's equator, and would elongate by additions (probably to its inner end) as the ring expanded outwards.

163. *Gravitation Upon the Expanded Earth-Crust.*—It has been already intimated that the attraction of gravitation varies not only with the law of inverse squares, but also in accordance with the surface condi-

tions. The present crust of the Earth being of a highly developed structure, the molecular motions of the Earth's connective atmosphere are correspondingly complex; but as the connective atmosphere passes inwards or downwards through the crust and into the heated central vapor, its molecular motions would gradually diminish in complexity until, when the vapor is reached, its molecular motions are reduced to their simplest form. Assuming that this complexity of molecular motions of the connective atmosphere, which would invariably accompany crust development, would cause bodies of a similar development with the crust to approach or fall towards it, and bodies of a dissimilar development to be repelled from it,—we can understand that the resistance to the outward expansion of the crust by the attraction of gravitation would thus be very materially diminished. As the crust moves equatorially, and eventually separates from the Earth, the connective atmosphere surrounding it would still maintain the complexity of its molecular motions, until its final disruption, when all the acquired complexity of motion would be lost. But the connective atmosphere remaining upon the Earth would evidently correspond in the simplicity of its motions to the primordial state of development there prevailing. This consideration by itself implies, therefore, that a body of a similar, development to that of the ring, if placed at rest between the ring and the Earth, would gravitate to the former, rather than to the latter. But how much this factor of gravitation would be antagonized by the density-factor, we do not appear to possess the data to determine. It seems probable, however, that the resistance to the outer movement of the ring would arise chiefly from the molecular connexions of the ring itself, and from the tension of the primary connexion with the Earth. And when the ring would eventually fracture at some weak point, the developed atmosphere which still surrounds it would draw the separated parts to the point of aggregation, perhaps with nearly as great an energy as it now exerts on falling bodies.

164. *Open Polar Seas.*—There can scarcely be any doubt that, owing to the equatorial expansion of thirteen miles from the Earth's center, which has already taken place, the crust in the neighborhood of the Poles must be much thinner than it would be if no such expansion took place. Whether this thinness of the polar crust is such at the present time as to cause the open polar sea, so persistently believed in by some mariners, is a matter to be determined only by future observation. Its existence is, however, clearly a deduction from the new theory either now or at some future time. And there are good reasons for believing that it really exists now. The coldest places, in the Northern Hemisphere at least, are not those nearest to the Pole, but those about 20° south of it—one focus being in northern Siberia, and the other in North America. Going north from these foci, the climate gets gradually warmer; and on the approach of winter, the birds of passage of these regions are observed to fly northwards.

165. *Inner Fringe of the Earth-Ring.*—As the crust would continue to expand at the Equator, the crust at the Poles would become more and more attenuated; and eventually, as the expansion proceeds, the polar crust would fracture down even to the original vapor. As this polar fracture continues to widen, the equatorial expansion would become comparatively more rapid, as one of the hindrances to such expansion, the molecu-

lar connexions of the crust itself, is thus to a great degree overcome. In the wake of the borders of the solar fractures as they move towards the Equator, would follow an inceptive crust of a liquid or scoriaceous nature, which would form through the cooling influence of ocean and air upon the exposed sea of vapor; and when the borders of the two polar fractures finally meet upon the Equator to form the inner edge of the solid ring, this neoplastic crust would form as the ring expanded outwards, an inner fringe, thinner and thinner towards the inner edge, until it ultimately dissolves into the ring-connexion.

166. *The Higher Forms of Life as Affected by These Changes.*—In this process of the evolution of our world, there does not appear to be any indication of sudden and serious catastrophes, at least until the stage of the ring-disruption is arrived at. Violent shakings and snappings would characterize the equatorial movement of the crust in the future, just as in the present and in the past, and very likely with just the same disastrous and fatal results; but these quakings and snappings would evidently occur in those regions underlaid with great thickness and extent of solid rock, and the disastrous ones only where this rock exists near the surface. For in those regions where the solid rock is wanting in the crust, the yielding would evidently be so slow and gradual as to be imperceptible; and where it is deep down beneath softer material, the jar would be about absorbed by the latter before arriving at the surface.

Aftér the polar fractures would take place, there would be geysers and volcanoes and earth-trembling for a time probably on a much grander scale than at present; but this would take place far from the abodes of man; and the most probable ultimate effect of the increased seismic activity at the Poles, would be the amelioration of the frigid climate now prevailing around them. But long prior to the separation of the crust in the ring form, gradual changes in the quality of the atmosphere, arising out of these disturbances, would presumably take place; and these changes might fatally affect, or at least depauperate, the higher forms of animated existence. And after the separation of the crust, the distribution of air, water, heat and gravitation upon it would evidently change to such an extent as to make the extinction of the higher forms of life no longer improbable. For the air that we now breathe would certainly not all appertain to the crust in its ring form, but probably such a part of it only as the mass of the ring is of the mass of the entire globe; and the same remark would also apply to the connective atmosphere; so that both air and gravitation would be very greatly modified upon the Earth-ring. Moreover the extreme heat to which all but the outer edge of the ring would be subjected from the fiery globe of the Earth, together with the probability that the remnant of the waters not gasified and thus retained by the Earth, would seek the outer edge of the ring and there form an ocean—all these probable circumstances confirm the belief that the essential conditions of all but the lowest forms of life upon every part of the world would be entirely subverted. What remained of the labors of our hands from the cruel erosion of the winds and the waters would be the sole mementos—alas! not mementos, but mere material and unrecognized remains—of our race; and these would presumably endure through the dreary and sterile ages of the ring-expansion.

167. *Disruption of the Earth-Ring.*—But the continual expansion of the ring would not forever be compatible with its stability as such. It must sooner or later yield to the ever-increasing centrifugal strain upon it. The final crash must come; and all the development which ages of ages have accumulated would pass into its original vapor. All the arts and sciences which we have been at such infinite pains to perfect; all our vast literature and almost perfected intellectual culture; all our grand monuments of architecture and engineering; our inventions, our plans our hopes, our fears, our loves, our memories—all melt away forever! Not the least vestige or trace would remain to tell the story of our being, our wealth, our splendor, our magnificence, our intelligence! From the vapor out of which we arose, to that vapor shall we return; and in that vapor shall our achievements be buried and our memories be eternally forgotten!

168. *The Sole Mementos of Our Race Which May Possibly Survive Us.*—It may indeed chance that a very slight trace of us would survive the awful convulsion. The fragments which by the tremendous energy of the crash are hurled outwards to wander through space, may bear some marks of our inscriptions and our handiwork. Prof. S. P. Langley, speaking of the same subject, from a different standpoint, gives utterance to the same thought in referring to the possibility of "a meteorite bringing to us the story of a lost race in some fragment of art or architecture of a lost world." At least the rocks in which are buried the solid remains of the lowest organic forms—these may partly escape destruction; and as they wander through space in after ages, they may fall upon some remote inhabited planet and convey to the beholder

the intelligence that other worlds than his own, somewhere in the realms of space, have been peopled with animate forms.

The eminent geologist, Dr. Hahn, has a few years ago completed a series of investigations upon some huge meteoric stones which fell from the sky in Hungary during the summer of 1866. Thin laminæ of these bodies, subjected to examination under a powerful microscope, have been found to contain what was supposed to be coralline and spongeous formations, and to reveal unmistakable traces of the lower forms of vegetation. The writer is aware that these alleged discoveries of Dr. Hahn are almost entirely discredited by men of science. But how far this may be owing to the totally different views on the origin of meteorites which these scientists entertain (by the most generally accepted of which such formations and traces would of course, be impossible), I shall not pretend to say, particularly as I have not examined Dr. Hahn's drawings. His conclusions, however, are in direct accordance with the new system; and not his only, but those of others who have impartially examined the subject.

Such traces as these are all that would remain of us and our surroundings; and apparently they can remain in no other manner. In all probability, then, the meteorites are our most permanent monuments; and alas! even they are but transient.

169. *Prelunar and Other Races of Mankind.*—After all, our fate is but the fate of other races of mankind which have, in all probability, preceded us; and will be the fate of others that will, in all probability, follow us. There appears to be no reason to doubt that our world was inhabited while yet the Moon laid upon its bosom. All the conditions which now

supervene in all likelihood supervened then: the same genial warmth of the Sun—interrupted for a time by an ice age, prior to the birth of Venus, as in our own epoch it has been just prior to the birth of Mercury; the same atmosphere, only somewhat more dense, perhaps; the same moisture, and the same ages on ages of crust-development. And these conditions would leave nothing to be desired more than we enjoy, to bring forth the suceessive steps of the ascending organic development up to the highest order of human intelligence; which may, indeed, have been higher than we have even the capacity to imagine. The time for such development had surely been ample, as, no doubt, it will be with ourselves.

But this prelunar race with all its supposable perfectness has dissolved away forever; and it may indeed be that another, but a different race will arise from their ashes, who, in their turn, will suffer a similar fate. We can assign no valid reason why the Sun, and even the Moon, should not eventually be inhabited. It is true that there is little or no evidence of the existence of air upon the latter at the present time; and in any event the air upon the Moon would be less for equal areas than upon the Earth, because the surface of the former is greater relatively to its mass than the surface of the latter is to its mass. But while this would evidently tend to modify organic beings as we know them, we have no right to suppose that it would render the existence of all organic beings impossible. It is also true that we see upon the lunar surface not the least sign or trace of water, nor even of its vapor in the lunar atmosphere. But we must remember that the Moon's crust at the present time may, in accordance with the new system of things, be so little cooled from its original state as to be still quite hot. If this should really be the case, as indeed many apparently undeniable changes in the craters of the lunar volcanoes* appears clearly to indicate, no water could possibly exist upon the Moon's surface; and the lunar gravity being at present comparatively small, and the lunar air so thin, the most reasonable form in which water could be supposed to exist there is in a gaseous state, or state of dissociation into its elements; in which it would not only be invisible to us, but would also very likely have little or no effect in refracting the rays of light which pass through it.

The Moon is a planet and the Earth is its sun. It evidently does not receive as much heat from the Earth at the present time as the latter does from the Sun; but it *may* receive more heat to-day from the Earth than it does from the Sun, owing to the differentiation of the connexions which has already been sufficiently discussed. The Sun also is a planet with respect to *its* sun; and its surface conditions may eventually be nearly the same, with respect to the existence of life, as now obtains upon the Earth.

170. *Continued Evolution, and the Limit at which the Process of Sub-division would Cease.*—The same process of evolution in various stages of advancement appears to be general. The Sun, the Earth, the planets, the Moon, the satellites—each is continually becoming colder at the surface and developing its crust; and as each has more or less of axial rotation, a centrifugal strain and an equatorial movement of the crust inevitably ensues; this eventually culminating in the separation of the crust in the ring form, and in the precipitation of the ring into a new and independent body.

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*See R. A. Proctor, *The Moon*, pp. 266-72.

And then the new bodies and the old begin the same process over again.

The question now arises—Where is this process of evolution to end?—for certainly it cannot continue forever. There is one limit beyond which we may postulate with temporary safety that the process will not continue, and that is the Atom. But between this limit, distant as it may seem, and the present stage, we apparently can assign no line beyond which it would not continue. The conditions of the process are an axial rotation, surface refrigeration, and distinct component elements. The first, all bodies have from the manner of their origin, the second, is a consequence necessary from the nature of the sphere, the peripheral atoms and molecules of which have naturally a greater freedom for transferring their motions to the great interplanetary and interstellar connective atmosphere than the atoms and molecules subjacent—and the third makes the separation into independent parts conceivable and possible. It may be, however, that the third condition is really unnecessary; that, in fact, the Atom itself, if its rotation be sufficiently great, would be amenable to the same process of subdivision as a planet; so that its definition alone would constitute its rather flimsy protection from the disintegrating influence universally manifested in nature.

We seem to have no alternative, therefore, than to regard it as a certain deduction from the new system that the process of evolution which we now see going on around us will continue to go on until all matter is reduced to its proximately ultimate divisions. And this applying to the universe as well as to any particular system, we thus finally arrive at the same state of things with which we started—a universal spheroid of approximately homogeneous vapor—which in turn develops a surface crust, and repeats over again the same grand evolutionary round of subdivision and segregation.

171. *Necessity for a Glimpse of the Successive Stages of Cosmical Evolution.*—It seems utterly beyond the power of the human intellect to follow the various and apparently innumerable stages of this grand round of physical evolution from the present down to the atomic stage. And yet, in order to obtain a true understanding of the phenomena of our environment, some glimpse of these various stages appears to be absolutely necessary. For, if the new system be the true one, these phenomena are results which have been determined by similar cosmic rounds of evolution in the ages of ages of the long, long past. Heat, light, gravitation, magnetism, and life, being now acknowledged on all hands as various forms of atomic or molecular motion, it behooves us to trace if possible the successive stages of evolution which lead down to molecular and atomic phenomena in order that we may rightly comprehend the mechanism by, or in, which they exist. Imperfectly as we can only hope to perform a labor of such magnitude, yet some general deductions may be arrived at which will be, perhaps, near approximations to the truth, and therefore valuable for our guidance.

172. *Expansion of Evolving Systems.*—As already intimated the orbit of Neptune probably extends outwards considerably beyond the primordial limits of the solar spheroid; and similarly, perhaps, with the Moon's orbit with respect to the primordial limits of the Earth, and with the orbits of sub-satellites, sub-sub-satellites, etc., with respect to the original limits of their respective primaries. But evidently the amount of recession

of the bodies immediately arising from the parent of a system would considerably depend upon the original velocity of rotation of that parent (Art. 100, *c* and *d*); that system in which the rotational velocity of the parent was the greatest obviously having the greatest amount of recession. In the Solar System the original rotatory velocity of the solar spheroid has been such as to cause a certain amount of recession; but in other systems of similar order this velocity may have been comparatively very small, so that little recession would take place; and in still others it may have been comparatively great, so that a much greater amount of recession would take place than in the Solar System.

In the Solar System the recession appears to be so great that the similar recession of bodies in the planetary systems of which it is composed, is not likely ever to interfere with the proper motions of these systems. For example the utmost reasonable recession of the Earth's system, or of the various sub-systems which would eventually compose it, can hardly be supposed ever to exceed 13,000,000 of miles from the Earth's center, or about half of the least distance that ever separates us from the nearest planet, Venus. And what is true of the Solar System in this respect would evidently be true of sister systems in which the original rotational velocity was as great or greater.

173. *Eventual Interference of Evolving Systems and the Results.*—But in a system where the original velocity was comparatively very small, and in which the recession of the bodies arising from its original spheroid was small in consequence, this, it appears, would not be the case. For such a system the component sub- or planetary-systems would be situated close together.

and as these sub-systems were eventually subdivided into lower and lower orders of systems, which might ultimately expand outwards, just as in the Solar System,* the obvious consequence would seem to be an eventual clashing of the motions of the component planetary, or sub-systems. In this clashing or collision of the bodies of neighboring systems, several things are to be noticed: (1) It would likely take place at first between the two outer sub-systems, because these are the older and their evolution consequently more advanced; (2) the bodies would collide from opposite directions with respect to their motions in all orders of systems lower than the planetary, because the planetary systems, of which they are the peripheral components, revolve in the same general direction, and thus about all sensible motion of the colliding bodies would cease, except their proper planetary motion; (3) the colliding bodies would be reduced to their original vapor, as the violence of their collision would probably be even greater than that of the aggregating matter in the disruption of a planetary ring, and (4) the gaseous masses thus resulting would gravitate inwards to the centers of their respective planetary systems, owing to the destruction of about all their motion around these and probably other subordinate centers; and as the products of the collision were falling into the center of each planetary system, each of the other bodies which revolve around this center would impinge upon and impart to them a portion of its own motion, so that, as the center was more and more approached, the rotation thus imparted to the vapor would be more and more accelerated. And endless varieties of these phenomena, depending upon the systemic order and the endless variations of the masses and motions of the colliding bodies, would obviously take place.

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* The planetary, or lunar, rotations in the system of a slowly rotating primary may be just as rapid as the similar rotations in the system of a rapidly rotating primary, as these rotations appear to have no connection or dependence whatever upon the rotations of their respective original spheroids.

174. *Effects of the Irregular Motions of Comets and Meteorites.*—But these varieties are but a moiety of the cosmic phenomena of this nature. The comets and meteoritic streams, which no doubt appertain to every other system as to our own, and which, quite possibly, form the greater portion of it, would continually fall at all inclinations and from all directions upon the plane of rotation of the system and collide with its component parts. Thus would arise motions of gaseous masses in planes at all inclinations to the systemic plane, and thus would the planetary system eventually assume a more and more globular form.

Even in our own Solar System, and in every system which had an equal or greater amount of primordial rotation, the agency of comets and meteorites would ultimately produce the same effect. For as the various subdivisions of the system continually subdivided and expanded, the probability of collision with the cometary and meteoritic bodies would become greater and greater, and every collision, by expanding the colliding bodies to still greater dimensions, would still further enhance the probability of such collisions in the future. So that whatever system we start with, great or small, or swiftly or slowly rotating, we ultimately arrive at about the same result—at about the same state of matter as that with which we began—a rotating spheroid of vapor.

175. *Corroborative Evidences.*—Glancing at the Sidereal System, we can not fail to observe thousands of

instances confirmatory of this conclusion to which the new theory has deductively led us. Here we find systems in all stages of subdivision and development, just as the theory has led us to expect. There are regular and irregular, resolvable and irresolvable, nebulæ in almost endless variety; and the Milky Way, which the theory indicates to lie in the equatorial plane of rotation of the Sidereal System, appears to be an intimate mixture of all these, together with innumerable stars of all orders of magnitude. We may briefly examine these various phenomena to see what interpretation of them the new theory furnishes.

Regarding the Sidereal System as originally consisting of a rotating gaseous spheroid in all respects, except that of magnitude, similar to the solar spheroid, from which all of its present members have descended as the result of the continued process of cosmical evolution in the past—we shall reasonably expect to find among these members some in which, owing to their primogeniture, the process has been carried to a much greater degree of subdivision than in our Solar System; and this, to the number of many thousands, is just what we observe.

(*a*) *The Regular Nebulæ.*—Basing our judgment on all available evidence, the irresolvable nebulæ are instances where this cosmical comminution has been carried nearly to its ultimate stage. These nebulæ are either globular (in which case they are called *planetary nebulæ*) or oval. Planetary nebulæ are regarded as very extraordinary objects, presenting round or slightly oval discs, in some cases terminating sharply, in others bordered with a softened haze. Their light varies from perfect equability to a mottled or curdled appearance, and from a faint white to a deep blue. These colors imply a nearly similar physical condition to that indicated by the spectroscope to prevail upon the white stars, a few of which approach to a faint blue. The spectra of the planetary nebulæ is of the discontinuous kind, and consists of a few bright lines, and their light is shown by Huggins and Lieut. J. Herschel to be monochromatic, or nearly so; which are the accepted indications of an incandescent gas.

The oval nebulæ are of all degrees of excentricity from moderately oval forms to ellipses so elongated as to appear almost linear; the latter, no doubt, being edge-views of still-flattened systems. These nebulæ evidently correspond to those systems in which the centrifugal tendency of the original rotation, and therefore the amount of expansion or recession, was great; while the globular or planetary nebulæ correspond to those in which the centrifugal tendency and consequent recession was small. The elliptic nebulæ are rarely resolvable. In all of them the density increases towards the center, and generally, so far as can be judged by their telescopic appearance, their internal strata approach more nearly to the spherical form than their external strata. Such of these as admit of resolution, or are of a resolvable character give continuous spectra, showing light of various degrees of refrangibility, and indicating incandescent solids or liquids; while those that are irresolvable give the bright-line spectrum characteristic of the planetary nebulæ.

Evidently by the new system of evolution the irresolvable nebulæ are the oldest, in which the process of planetary subdivision has been carried nearly towards its ultimate limit; while the more and more resolvable nebulæ are those in which the process of subdivision has been less and less advanced; the least resolvable of which therefore consists of innumerable starlets or planetoids which are individually so small as to be barely discernible in telescopes of the highest power. Of this latter kind is the elliptic nebulæ in the girdle of Andromeda which in a reflecting telescope of 18 inches aperture is quite irresolvable; but which with the exquisite defining power of the great achromatic at Cambridge, U. S., though not itself clearly resolved, was found to be thickly sown over with visible minute stars so numerous as to allow of 200 being counted in a field ⅛ of a degree in diameter.

By the current cosmogony, the irresolvable nebulæ are the youngest portions of the Sidereal System—portions in which the primordial "world-stuff" is just aggregating by gravitation into the parent spheroid of some future solar system; and the resolvable nebulæ are somewhat older members in which the process of aggregation is more advanced—the elliptic form and innumerable minute bodies of which they are composed thus of course remaining unaccounted for.

(*b*) *The Irregular Nebulæ.*—Besides these nebulæ of regular form there are other nebulæ of forms that seem to us very irregular. These are noted for their very great extent, and they have also this one important characteristic in common—a location in, or very near the borders of the great Milky Way. Now since the Milky Way is supposed to be in the equatorial plane of the Sidereal System, we might expect to meet here with innumerable nebulæ together with stars of all orders of magnitude, just as in the equatorial plane of the Solar System we meet with the great bulk of the regular bodies which it contains. And this is just what we find. The stars are indeed numerous here, and the vast majority are both comparatively small and distant; indicating that the process of subdivision has been carried on at the periphery of the Sidereal System to a greater degree than at the central regions, just as, according to our theory of sidereal segregation, it should be. And in still further confirmation of this view we observe that beyond all of these stars are situated the irregular nebulæ. Sir John Herschel, after observing one of these nebulæ through his telescope, says: "The conclusion can hardly be avoided that in looking at it we see through and beyond the Milky Way, far out into space, through a starless region." Beyond, or rather in the outskirts of the Milky Way, the nebula undoubtedly lies; but its relative farness and its starless environment, while they are suggested naturally enough by the utter darkness of the regions beyond, are in all probability imaginary. Moreover these irregular nebulæ are found chiefly in groups, which also accords with the theory; for it is those systems first originating in the Sidereal System in which the nebulæ would chiefly appear; and these would occupy separate spots in the equatorial plane, just as our planetary systems do in the equatorial plane of the solar rotation. The remaining feature of irregularity of form may be assignable to two apparently sufficient causes: first, the vast number of these superposed upon one another in the line of sight, and second, their immense distance from us which prevents our seeing them in all their completeness. With regard to the first cause, Sir John Herschel, speaking of the Magellanic Clouds, or the nubeculæ major and minor, visible to the naked eye in the Southern Hemisphere, and which are quite probably nothing more than irregular nebulæ in a less distant region from us, says: "When examined through powerful telescopes, the constitution of the nubeculæ, and especially of the nubecula major, is found to be of astonishing complexity. The general ground of both consists of large tracts and patches of nebulosity in every stage of resolution, from light, irresolvable, with 18 inches of reflecting aperture, up to perfectly separated stars like the Milky Way, and clustering groups sufficiently insulated and condensed to come under the designation of irregular, and in some cases pretty rich clusters. But besides those, there are also nebulæ in abundance, both regular and irregular; globular clusters in every state of condensation; and objects of a nebulous character quite peculiar, and which have no analogue in any other region of the heavens. Such is the concentration of these objects that in the area occupied by the nubecula major not fewer than 278 nebulæ and clusters have been enumerated, besides 50 or 60 outliers."

It is this grouping together in the immensity of space to which the irregular form of all such nebulæ may chiefly be ascribed. For, however regular may be each individual component nebula, yet these to the number of many hundreds, and probably thousands, may be so arranged naturally as to present a fantastic or capricious appearance—just as the configuration of the planets of the Solar System may never have a regular form as a whole, although each planet is itself of a regular form, and has a regular motion around a common central body.

Another circumstance also which would tend to render nebulæ amorphous, and especially such as are of a resolvable nature (as the irregular nebulæ almost invariably are in whole or in part), is that many of their component bodies or planetoids must, at their extreme distance, be invisible to us. Annular nebulæ, *e. g.*, are probably systems in which the peripheral sub-systems, owing to their expansion, as already noticed, have collided together, the resulting vaporous mass becoming self-luminous, and having so little cohesion as to be distributed over the entire path of these sub-systems; while the inner sub-systems, composed of planetoids which are not self-luminous, remain invisible.

The spiral nebulæ are readily derivable from the annular, when sufficient time is allowed for many collisions of the component sub-systems and for the slow gravitation inwards of the resulting vaporous annuli in the manner already described. Nebulous stars would result from a still longer continuation of this process, when the vapors would nearly all have aggregated at the center. And besides these it may be added that the irregular action of cometary bodies would obviously constitute a third cause of the anomalous forms which nebulæ so frequently present.

(*c*) *Observed Changes in Nebular Forms.*—In further confirmation of this view, various changes of appearance have been suspected in the irregular nebulæ which seem to be clearly attributable to such relative motions of their component parts as the theory here predicates. Owing to their great distance from us, the theoretical slowness of their angular motions, and the invisibility of all but their incandescent and larger components, only small and almost imperceptible changes in their appearance are to be looked for; and these, even in comparatively short periods, we have good reasons for regarding as actually taking place. The Magellanic Clouds, according to Sir W. Herschel, have undergone important changes during a lifetime

(*Phil. Trans.* 1811). The great nebula in Orion is now generally admitted to be in process of change. The nebula surrounding the variable star, Eta Argus, is also subject to great changes. And probable movements are shown by Prof. Holden to take place in the Omega nebulæ.* Prof. Holden says: "These drawings show that the western end of this nebula has moved relatively to its contained stars from 1832 to 1862, and again from 1862 to 1875, and always in the same direction." And several other instances of this kind could be mentioned.

Beside these changes of nebular form, movements of the nebulæ as wholes also take place. "Several objects observed as nebulæ are now missing from the heavens." "There are cases in which a nebula, undoubtedly such, have either disappeared and reappeared in the same place, or has undergone some remarkable changes of brightness; or, lastly, has been observed as a conspicuous object in a part of the heavens so well known as to make it exceedingly improbable that it should have escaped all previous observation."† These, as well as nearly similar phenomena among the stars, are very probable, owing, at least in part, to the proper orbital motions of our own system and of the systems containing these bodies. Aside from the rotation of the Sidereal System as a whole (in which, however, every member probably has a different angular and absolute velocity) nearly every body which that system contains has an indefinite number of minor rotations as members of the various sub-systems of which the Sidereal System is composed; and by virtue of one or several of these rotations, some of which are

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American Journal of Science and Art, III, XI, 341-61.

† Sir John Herschel, *Outlines of Astronomy*, Note (K.)

of very great amplitude, the bodies and ourselves are continually either approaching towards, or receding from, each other; the approximations obviously causing the new appearance, or the greater brightness, of the bodies, and the recessions causing their disappearance, or diminished brightness. These phenomena are commonly ascribed in the current theory to practically the same causes.

(*d*) *Temporary Stars.*—But other phenomena are currently attributed to other causes than those which are here indicated; among which are temporary stars and variable stars of regular periods. Temporary stars are those which have appeared from time to time in different parts of the heavens, blazing forth with extraordinary luster; and after remaining awhile apparently immovable, have died away and left no visible trace. According to Humboldt, twenty-one such stars were recorded during the interval 134 B. C. to 1848 A. D. Such stars are recorded to have appeared, one, 125 B. C., visible in the daytime; another, 389 A. D., remaining for three weeks as bright as Venus and eventually disappearing entirely; others in 945, 1264 and 1572; the last, in Cassiopœia, studied by the celebrated Danish astronomer, Tycho Brahe, surpassing both Sirius and Jupiter, when brightest, and being visible at mid-day. It began to diminish in December of the same year, and in March 1574, had entirely disappeared. Also in October 1604, a star of this kind and not less brilliant burst forth in the constellation of Serpentarius, which continued visible till October, 1605. In May 1866, one appeared in the Northern Crown exceeding the second magnitude in brightness. This star was spectroscopically investigated, and, according to Huggins "the spectrum indicated two distinct sources of light, each producing a separate spectrum. One was a continuous spectrum crossed by dark lines similar to that yielded by the sun and most of the stars. The other consisted of four brilliantly bright lines. The first spectrum showed a photosphere of cooler vapors giving rise by absorption, to the dark lines. The other spectrum showed the presence of an intensely luminous gas which was apparently hydrogen at a higher temperature than existed in the photosphere of the star."*

Now these phenomena correspond precisely with those of a ring-disruption upon some sun in a distant region of the Sidereal System. Prior to the disruption, the ring itself and its parent body would be invisible to us owing to the distance, comparative smallness, remoteness of relationship, or possibly all three; but after the disruption, the ring-substance would be reduced to its original vapor, all of which aggregating into one mass of intense heat and luminosity, would very reasonably become visible to us. This is clearly indicated also by the two spectra above described: the gaseous spectrum of bright lines obviously belonging to the newly vaporized ring-substance, and the other spectrum of dark lines belonging to the original sun upon which the ring was generated, and partly, perhaps, to comets and meteorites originating in the collapse. These latter bodies, as already intimated, may contain by far the greater portion of the ring-substance, and so may give rise to a separate spectrum of their own, to which that of the original sun might also contribute. To the abstraction of these bodies from the general aggregated mass and their wandering apart into distant regions (together with comparative smallness of the bodies) would also be reasonably attributable the grad-

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*Alexander Winchell, *World-Life*, p. 514.

ual waning or dying away of the new star. The cometary velocities, while really great, would yet owing to their distance, require months, and perhaps even years to separate so widely as to dissipate into invisibility; while, when the individual bodies were apparently close together, though really separated perhaps by planetary distances, the whole would be visible in one glare as if produced by a single body at a distance not so great. It was formerly thought that these stars entirely disappeared; but, as a further confirmation of the new views: "it is now maintained that none of the temporary stars are new originations, and that none of them have disappeared from existence, if even from visibility. That occurring in the Northern Crown is still telescopically visible; and it is maintained that the new stars of Tycho and Kepler may still be seen,"* exactly as the new theory predicates.

The explanations usually given of these "temporary stars" are, (1.) Collisions of planets precipitated inwards with their suns. This if possible, would certainly account for the sudden blazing forth of the planetary and solar substance into vapor. But a very apparent and fatal objection to it is the brief duration of the phenomenon; as, in the absence of cometary and meteoritic abstractions, a pair of united worlds thus made incandescent would obviously require a much greater time for the dissipation of their heat. (2.) Eruptive action on an incrusting globe, just as volcanic eruptions have taken place upon our own world. But this is clearly inadequate. In the first place, either as lava or as gas, it could hardly be supposed to take place over the entire surface of a world at once; and in the second place, the two spectra observed are

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*Alexander Winchell, *World Life*, p. 515.

thus entirely unexplained, as only one solid or liquid body surrounded by a luminous gas is implied; which accounts for only one of the observed spectra. (3.) Collision of a darkened star with a cometary body. But this is open to the same objection as explanation (1) and both explanations (1) and (3) are open to the second objection to explanation (2) as accounting for only half of the observed phenomena.

(*e*) *Double, Triple, and Multiple Stars.*—Moreover we have in other regions further evidence supporting the views here advanced. The double, triple and multiple stars are now observed to be minor systems, the visible members of which are incandescent. Double stars are frequently observed, numbering between 4,000 and 5,000, while triple and multiple stars are very rare, numbering only about 53 in all. The former would evidently be composed of a central sun and a new planet of recent origin revolving around it, several of them having been actually traced through complete revolutions, and some of their periods or years varying from 36 to 1,200 of ours. The triple and multiple stars similarly imply the nearly contemporary origin of bodies corresponding to both planets and satellites in the same system, which seems to be fully corroborated by the extreme minuteness of all but one or two—sun and planet—of the component bodies.

(*f*) *Periodic Stars of Short Period.*—We are thus naturally brought round to the phenomena of the periodical stars, which in all probability will be found to have their true explanation based upon the same facts. These stars alternately increase and diminish in brilliancy, the changes having fixed periods varying from two days to about a year. The star Algol, or Beta Persei, *e. g.*, is usually visible as a star of the second magnitude and continues so for 2 d. 13½ hrs., when it suddenly begins to diminish in splendor, and in about 3½ hrs. is reduced to the fourth magnitude at which it continues about 15 min. It then begins to increase and in 3½ hrs. more is restored to its usual brightness, going through all its changes in 2 d. 20 hrs. 48 min. 54.7 sec. Goodricke, the discoverer of these changes took the view that they were caused by the revolution round the star of some opaque body which, when interposed between us and the star, cut off a large portion of its light. This explanation does not appear to incur any serious objection, and is quite in harmony with the new theory. If it be the true one, however, the velocity of the opaque body round Algol must be very great, or the real dimensions of Algol and of its opaque planet comparatively very small. Another explanation suggested by the new theory seems to account for it equally well, or perhaps better. This explanation is that, instead of an opaque body revolving round a self-luminous star, the two bodies are self-luminous, the smaller revolving round the larger in an orbit, the plane of which is coincident with the line of sight. Two minima and two maxima would thus occur in each revolution, the former occurring at each conjunction of the revolving body with the Earth, and the latter at each quadrature. The distance between the bodies in the latter case, though really great, perhaps, would appear so minute, owing to the great distance of the observer, that the two bodies at their greatest angular distance apart would be indistinguishable one from the other. So that the effect of their separation from one another in the line of sight would be in effect to increase the magnitude of an apparently single body. The short minimum of 15 min., the long maximum of some 61 hrs., and the comparatively short periods of waning and brightening, each 3½ hrs., appear to be thus fully accounted for, all in a semi-revolution; the waning and brightening periods being so short because the motion of the revolving body to and from minimum is at right angles to the line of sight, and therefore apparently rapid, and the maximum period so long because the motion of the body at that time is nearly parallel with the line of sight, and because the amount of apparent separation or approximation of the bodies with respect to that line is imperceptibly small, except for comparatively short times at the beginning and closing of each semi-revolution.

The same explanation also applies to Delta in the constellation Cepheus, its period being 5 d. 8 hrs. and 47⅜ min., of which the interval between minimum and maximnm is only 1 d. and 14 hrs. The periodical star Beta Lyrae appears to admit of no other explanation but this, as it has two minima and two maxima, owing evidently to a considerable inclination of the orbit-plane of the revolving body to the line of sight, so that the latter approaches near, but not to, the disc of the central star. Its period was formerly stated at between 6 and 7 days, as its light certainly underwent a remarkable diminution and recovery in that time. But the more accurate observations of M. Argelander have led him to conclude the time-period to be 12 d. 21 hrs. 53 min. 10 sec., in which a double maximum and minimum takes place.*

(*g*) *Secular Variations of Periodic Stars.*—In addition to this subdivision of the whole interval of change (corresponding to an entire revolution) into two semiperiods (corresponding to semi-revolutions), we are presented, not only in the case of this star, but in the case of about every periodical star, with another instance of slow alteration of period, which has all the appearance of being itself periodical. This alteration is a gradual lengthening of the period, slow at first, then much more rapid, then slow again, followed by a diminution of the period in all probability through the same gradations. In the case of the last mentioned star, the period of variation was increasing from 1784, the epoch of its discovery, to the year 1840, after which it began to diminish. In the case of Algol, a comparison of the earlier with more recent observations indicates a diminution in the periodic time, not uniformly progressive, but "actually proceeding with accelerated rapidity, which, however, will probably not continue, but, like other cyclical combinations in astronomy, will by degrees relax and then be changed into an increase according to the laws of periodicity which, as well as their causes, remain to be discovered."

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* *Astron. Nach.*, Nos. 417, 455, 472.

It seems strange that the simple explanation of this slow alteration suggested even by the analogous phenomena of the Solar System, has not previously occurred to investigators of this subject. All astronomers are aware that no body in the whole visible heavens is at rest. Observation has demonstrated the occurrence of movements even of the fixed stars in directions at right angles to the line of sight, and the spectroscope reveals to us even the actual rate of their motions *in* that line; which appears to be quite comparable with that of the Earth in its orbit around the Sun. Now granting that the variable stars are approaching towards, or receding from, us, in virtue of the proper motion of these bodies, or of the Solar

System, or of both together—the light which travels between us and them at the rate of about 190,000 miles per second would come to us more slowly when they are receding, than when they are approaching. For every 190,000 miles they recede from us, the duration of their phenomena, would apparently, though not really, lengthen one second, and for every 190,000 miles they approach, the same would be similarly diminished. We know this to be the fact in the case of the transit-periods of Jupiter's sattelites, which are found to lengthen slowly and gradually when the Earth recedes from, and to diminish slowly when it approaches towards, that planet; the total variation of all the transit periods occuring between opposite points of the Earths' orbit, or in the course of about six months' time, being about 17 minutes. And there appears no reason whatever to think that the slow alterations of changes of the periodic stars (in the case of which, however, the velocity of the motion causing the variation is not so great as that of the Earth's motion around the Sun) are not attributable to the same cause.

(*h*) *Periodic Stars of Long Period.*—There are some periodic stars the phenomena of which, however, can not be due to the revolution of one incandescent body around another; these in about every instance being of comparatively long periods. The most remarkable of these is the star Omicron in the constellation Cetus, or Mira Ceti, its period being 331 d., 8 hrs., 4 min., 16 sec. At its greatest brightness it is sometimes equal to a star of the second magnitude. After about a fortnight, it begins to decrease in luster, and at the end of five months becomes invisible to the naked eye, in which state it remains about five months more, finally brightening up as before in the remainder of the period. It does not always return to the same degree of brightness, however, nor increase and diminish by the same gradations. Of these phenomena there appears to be little or no explanation, other than that they are, as the named Mira implies, strange and wonderful. In the light of the new theory, however, they are clearly referable to a system nearly in its ultimate stage of evolution. The collisions which we have already noticed as taking place between the expanding sub-systems into which any particular system would be divided, would, in their initial stage, very probably not occur at one time only, but at many successive times; and at each collision a portion of the colliding systems would be vaporized. The resulting incandescent vapor, while it was collected at one spot, would be brightly visible to us; but as it was dissipated between the paths of the colliding bodies (in which it would ultimately appear, after many reinforcements, as an annular nebula), it would become less and less apparent and would finally diffuse and dwindle into invisibility. This theory appears to explain fully the facts of the case; and no other theory appears to be tenable. A falling planet, or colliding comet, is manifestly precluded by the regularity of the occurrence; and Zollner's theory of rotation of a body having sides of different degrees of luminosity, while it provides for the regularity of occurrence, is in turn precluded by the brief duration of the brightness as compared with the long period of invisibility, as well as by the suddenness with which maximum brilliancy is attained, while the waning of that brilliancy requires nearly half of the entire period. Goodricke's theory of occultation by an opaque body revolving about an incandescent star is, for the same reason, entirely inadmissible.

The most reasonable, and by far the best supported by spectroscopic and other evidence, is the explanation (very similar to the one here suggested) offered of these phenomena by J. Norman Lockyer in a series of papers in volumes 39 and 40 of *Nature*. In these papers he accounts for the phenomena of periodic stars by collisions with meteoritic swarms. The regularity would thus be owing to the passage of the body presenting the changes during its orbital motion through a swarm of meteorites, whose orbit intersects its own, the collisions with the meteorites at the point of intersection causing the evolution of incandescent vapors to which the brightness is due. This explanation, with little exceptions, is about the same as that which the new theory suggests. The periodicity by the latter would be determined by the synodic period of an expanding sub-system of planetoids with a neighboring expanding sub-system around a common center of revolution; the collisions occurring when the inner sub-system would overtake the outer. The explanation of meteoritic swarms, however, appears to be open to one or two slight objections from which the latter is free. In the first place, the number of meteorites encountered during every passage of the body through their orbit would not reasonably be the same, and, as in the case of our own world passing through the orbits of the August and November swarms, it is even probable that at times scarcely any meteorites whatever would be encountered. Thus the maximum brightness of the body would vary probably from the minimum up to the highest magnitudes, and the intensities of any two maxima would be hardly ever alike. And in the second place it can hardly be regarded as probable that the orbital paths of the swarm and of the body would continue to intersect one another for such long periods of time; for as the two would probably belong to different systems of some order or other, they would obviously soon part company owing to the divergence of the wider motions of the different systems to which they would belong.

176. *The General Process of Subdivision thus Implied.*—Now these processes of subdivision which are taking place in the nebulæ and the periodic stars are but continuations of the processes which are taking place in our own Solar System. The latter will be reduced by the continuation of the process now going on, to the nebular stage; the nebulæ will be still further comminuted, expanded and amalgamated; until finally we have a universal nebula similar in all respects save magnitude and density to the planetary nebulæ which we now see in the heavens and similar in all respects save motion to the universal nebula with which we started.

177. *Nature of the Ultimate Subdivisions of Matter.*—We have thus briefly and very imperfectly traced the segregation of any particular original spheroid having a certain amount of axial rotation into subordinate spheroids each revolving round the nucleus of the original spheroid in the plane of its equator; the segregation of each of these in a similar manner into smaller spheroids revolving round both the subordinate spheroids and the genetic spheroid; and so on until a stage is arrived at nearly like that with which we began. Now if this process had taken place in a regular manner, without interference from neighboring parts, or from erratic bodies, the motions of the ultimate components of the ultimate spheroid would be of a very complex nature. But

obviously even in this case, all of the ultimate components would not possess the same number of motions nor velocity of rotation. For, in general, the central components being the most recently formed would have comparatively simple motions (*i. e.*, around only a few different centers), the velocity of which, however, would be comparatively very great; while the peripheral components, being the older, would have motions of greater complexity (or round many different centers), but of a less degree of velocity.

But it does not seem probable that, in a spheroid thus reduced to its ultimate constituents, motions of very great complexity would be permanent. The intricate net-work of connexions would undoubtedly resist complicated movements of parts having such extremely small masses; and would eventually resolve itself into comparatively simple bonds between contiguous components and between contiguous groups of components. For, as the subdivision continued, the mass (and therefore in general the momentum) of each component would decrease while at the same time the massiveness of the connexions through which the components have to move would increase (owing to the continual formation of new ones); and thus would a more and more powerful brake be put upon complex motions of the parts as the subdivision proceeds.

The result, then, would be an arrest of motions around distant subordinate centers; the arrested motion probably going to augment the equal angular rotation of the resulting spheroid as a whole. The connexions of the arrested components would probably be appropriated in part by those of neighboring components; but these disused connexions would chiefly exist, in all probability, as an independent and special form of matter. But the evidences confirmatory of this, lies in the domains of the molecular phenomena of electricity and magnetism; and must therefore be deferred until these phenomena are discussed. The lowest ultimate components thus arrived at would be a primary body incapable of further subdivision with the rate of rotation which it then posesses, and one or more bodies connected with it and circulating around it. A higher form of ultimate component also might consist of a similar central body around which circulates a second similar body which is itself a center for a third circulating body, or even with one or more of these bodies themselves compound.

That the circulating motions of these components would be arrested by the connective substance would not follow from the same causes that arrested the motions round more distant centers, for the reason that whereas the latter would be resisted by a multitude of connexions subtending between all bodies among which they moved, the former would be resisted only by the few connexions between its own primary and the neighboring primaries.

If instead of a system in which no interference by expansion of component parts or action of erratic bodies, was supposed to take place, we consider the case of a system in which expansive interference would occur, it will be seen that the same motions would be arrested by it, as by the eventual resistance of the connective substance, and no other. In the collision of an inner with an outer sub-system revolving around the same center, the orbital revolution of the latter would be increased and that of the former diminished, while it is always the wider of the revolutions in the colliding sub-systems themselves that would be thus destroyed. So that, in either case, we arrive at the same result—an accelerated, equable rotation of the resulting spheroid as a whole; and a simple, together with some slightly compound, systemic motions of its ultimate components.

And considering also the agency of erratic bodies, such as comets and meteorites, we can still ascribe nothing to them that would seriously interfere with the same result. As for the rotation of the resulting spheroid as a whole, as these bodies would fall upon it about equally from all directions, they could influence it in any particular direction but little, while the larger intermediate motions would suffer at least partial arrestation. And as for the motions of the ultimate components, they can only be met and arrested by the motions of bodies of a magnitude similar to their own, and even then, perhaps, but rarely, if ever.

The collisions of two masses of matter, if it occurs with the tremendous energy implied by planetary velocities, would, indeed, not only arrest the motions of a portion of the elementary systems, but also give rise to their motion in a reversed direction with a still greater energy; while the motions of another would not suffer arrest, but acceleration wholly. In mechanical collisions of any kind there can but comparatively an extremely small number of bodies of elementary systems be brought to rest; first, because it is highly improbable that the velocity of the colliding masses would be exactly equal to that of the bodies of the elementary systems; and, secondly, because, even if the velocities were exactly equal, it is equally as improbable that the direction of collision and that of the elementary rotation would by exactly opposite. And the very few elementary bodies which might be thus brought to rest would be again immediately started in motion by their connexions with the accelerated adjoining bodies. Thus the result we have arrived at by the regular process of cosmical segregation remains practically unaffected by the various accidental contingencies, such as systemic interference, cometary and meteoritic impacts, ring-disruptions, etc., to which that process may be subject.

The ultimate element of matter in its simplest form at which we have thus arrived would consist of *a central body*, *a secondary body*, revolving around it, *a primary connexion* joining the two, and *various secondary connexions* joining the bodies to neighboring elements. Moreover, each of the two bodies, according to analogy, would have *a connective atmosphere* which would permit the expansion of the element when the velocity of revolution of the secondary body was increased; and finally each of the elementary bodies would also have *a certain amount of axial rotation.* This axial rotation of the primary body, if it should be the remnant of an originally large spheroid, would be extremely rapid; and the more rapid the rotation of the primary body, *cæteris paribus*, the more rapid would be the revolution of the derived secondary body also. What it is that performs this rotation and revolution we do not know and may never know, nor even conceive or imagine; and it seems even to be utterly futile to speculate about it. The ultimate nature of the elementary connexions seems equally as inscrutable as that of the elementary bodies. To both entities the name of matter or substance may properly apply; but the connexion, though not theoretically any more indivisible than the body, may, perhaps, be regarded as perfectly homogeneous, whereas its analogue, the planetary connexion, can only be regarded as composed of simple and compound elements.

178. *Ultimate Scientific Conceptions.*—It may now be said that we have taken a panoramic view (though no doubt an extremely imperfect one) of one Grand Round of cosmical evolution. How many similar Rounds the Cosmos had previously undergone we probably can never tell, any more than we can tell how many may take place in the future. It does not now seem conceivable that the ultimate elements of matter could have been evolved out of a perfectly homogeneous magma wholly without part or division in such a cosmical process as is now taking place, because there would be lacking the individual components which, in the surface-contractions, are to approach each other. In fact it appears that we have now arrived at the "most general conception" in which all other conceptions must be included; and which, therefore, must itself remain inexplicable—at least until we know somewhat more about the universe than we do at present. The nature of the process by which Matter first became subdivided into component elements is just as inscrutable as is the nature of the stuff of which the elementary bodies and connexions consist. These are the present limits of our knowledge—a Universal Whole of nearly homogeneous vapor, made up of distinct component parts, and the Atom, or ultimate component part itself. Beyond either of these limits, our intellect can not soar, for nothing there appears to render it support or rest.

179. *Results of a Grand Round of Cosmical Evolution.*—But premising these limits, we can trace with a tolerable degree of clearness the processes which would naturally take place, until almost an eternity of evolution brings us again to a state of things appar-

ently similar in all respects to that with which we started. But this vast cycle of evolution would surely cause some change in the pre-existing state of things. Some permanent results would be thus attained, and would be more and more enhanced by succeeding cycles. What, then, are these results? From what we have already gone over we can, with a fair degree of confidence, deduce the following: First, an expansion of the Whole outwards into space owing its axial rotation (either previously acquired as suggested in Art. 110, or original); second, an acceleration of the previous rotation of the Whole; third, an acceleration of the rotation of the ultimate component parts of the Whole (either previously acquired, or original), and this very probably accompanied by a subdivision of these parts owing to this increase of rotation; and fourth, an accelerated revolution of the secondary components of the ultimate elements of matter around the primary components of these elements, necessarily resulting from their accelerated rotation. These, then, are our most general deductions. The sole products of the myriads of ages of evolution and disolution, development and destruction, pleasure and pain, life and death of any one Round of cosmical segregation are a mere gain of Motion in Time and an increased encroachment of Matter upon Space—as compared with these elements in the preceding Round.

180. *The Universe of Molecular Phenomena Now Opening Before Us.*—We are thus ultimately led by the new theory into the microcosmic domains of the molecule. There now opens before our view the actual mechanism of the phenomena of heat, as manifested in its reflection, refraction, transmission, conduction, and effects upon other bodies; of the phenomena of light, as

manifested in its transmission, reflection, refraction, double refraction, diffraction, polarization, and chemical effects; of the phenomena of gravitation; of the phenomena of electricity and magnetism—which alone constitutes a world of wonderful yet simple mechanism; of the phenomena of sensation, and even of vital and of mental action. We have already discussed some of these phenomena in their cosmical relations. We have now to examine them in their molecular relations and thus interpret the mechanism of the varied manifestations in which they affect our senses.

Thus are the grosser phenomena of the universe seen to blend gradually and insensibly into its most refined phenomena; and Prof. Huxley's words apply here with peculiar fitness: "Living matter differs from other matter in degree and not in kind; the microcosm repeats the macrocosm; and one chain of causation connects the nebulous original of suns and planetary systems with the protoplasmic foundation of life and organization." So, also, the words of Prof. Mendeleef: "The unseen world of chemical changes is closely analogous to the visible world of the heavenly bodies, since our atoms form distinct portions of an invisible world, as planets, satellites and comets form distinct portions of the astronomer's universe."

181. *Assigned Limit of this Work.*—But we are here constrained to pause—not, indeed, owing to the magnitude of the work which yet remains to be done, although it is by no means small, or to any inherent difficulty which, in connection with the views here advanced, it involves. Most of the ground has been already gone over, and as far as could be seen at a first view, certainly no greater obstacles appeared than has been met and easily surmounted in the domains trav-

ersed in this volume. A few of the results derived from this further investigation have been mentioned in the beginning of this work (Arts. 22 to 26 inclusive), and with these, although they are but very meagre returns from so vast a field and from the splendid harvest it contains, we must, for the present, remain content.

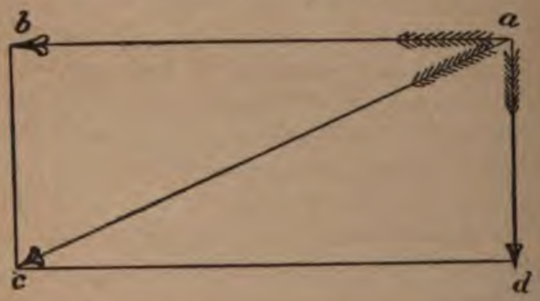
It does not seem unreasonable to think that the foregoing pages contain sufficient evidence to demonstrate the utter fallacy of one of the two theories here discussed and, at least, the approximate correctness of the other; so that the introduction of still further evidence for the purpose of demonstrating the truth of the one or the error of the other seems quite superfluous. When a desire for the further facts which the new theory may teach becomes generally manifested, as prompted by the conviction of the trustworthiness of that theory which the evidence already presented seems more than adequate to inspire, the remaining portion of the work will be readily forthcoming. And if no such desire is manifested in consequence of such a conviction, it would be a mere waste of words to adduce even all the evidence which the theory holds in reserve.

182. *Connective Resistance to the Motions of the Heavenly Bodies.*—There is but one thing further that will here engage our attention, and that is the resistance to the motions of the heavenly bodies which the connective substance would evidently offer. Of course, this resistance would not be greater in the case of the connective substance of the new theory than it would be in the case of the ethereal medium of the old theory. In either case there would obviously be friction when a body passes through a material medium. And, since there appears to be no diminution of the

planetary motions, owing to this cause, it becomes a proper matter of inquiry how these motions could possibly be maintained in opposition to the resistance which that medium, it seems, must necessarily offer to them.

Of this difficulty it appears that little if any explanation has previously been offered. And the one which is here suggested—if one indeed it may properly be called—is, in view of its extreme simplicity and familiarity, offered with the greatest diffidence.

183. *Possible Cause Counteracting the Connective Resistance.*—It seems to be generally admitted that the cord which confines a revolving body to a circular path



offers no resistance whatever to the motion of the body in that path. But, as a matter of fact, does not the action of the cord quantitatively modify the actual path which the circulating body pursues? It is true that a pull acting upon a body at right angles to the direction in which it is moving would neither increase nor diminish the quantity of its motion *in that direction.* But since the pull *changes* the direction of the motion, it seems to follow from this very fact that the path of the body, in a unit of time, would be greater in the changed than in the unchanged direction. If the projectile motion of the body in a unit of time be such as to make it describe the path *a b*, and the body be subjected during that time to a pull which would cause it to move a distance *a d* at right angles to *a b*, then does it not clearly follow from the composition of forces that the body would describe in the same unit of time the path *a c*, or the diagonal of the rectangle of which *a b* and *a d* are the sides?* And if the inward pull upon the body has thus caused it to describe a *longer* path in a unit of time than it would describe in the absence of that pull, has not that pull, as a matter of fact, actually increased the absolute velocity of the body? It certainly seems that it has; and since the inward pull operates upon the body continually, it would thus follow that the absolute motion of the body in its circular path, other things equal, would be continually increased. And the explanation here suggested is that approximately what the resistance of the medium diminishes the absolute motion of the body, the radial pulling of the primary cord increases it.

In corroboration at least of an approximate equivalence of the two opposing tendencies, it is to be observed that while an outer planet moves in a less dense medium than an inner planet, its radial pull, on the other hand, is also less; and the inner planet moving through the greater density has a relatively great radial pull to compensate for the greater density of the medium. Of course this greater radial pull on the inner planet would not fully compensate for the greater density of the medium, if the resistance offered by the latter varies as in gross matter, or matter as we are sensible of it. But this ratio may not hold in the former case as in the latter. In other words, an increase of density of the connective substance (which at the planetary distances would be at least as much rarer than the most perfect vacuum, as that vacuum is rarer than ordinary matter) does not necessarily imply a proportional increase in the resistance it would offer to moving bodies. The resistance would obviously be greater in the greater density, but very probable in a somewhat smaller ratio. And thus, perhaps, even the exact equivalence of the resistance offered by the connective medium to the absolute orbital motion of a planet and the assistance of that motion by the radial pull would in all cases be continually maintained.

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*See Diagram on preceding page.

184. *Retrospect.*—To summarize the results of our investigation so far as it has been carried out would be little less than a repetition of what has already been said. Only the more important results have been given, and these in the briefest possible form which would convey them to the reader's mind. The entire work is little more than a summary of the more detailed investigations which it was necessary for the author to discuss for even the approximate determination of the given results; and a summary of a summary would scarcely be more than a mere recapitulation of the subjects discussed. A final very brief survey of the most important results obtained may not, however, unfittingly close our investigation.

In the first place, then, we have taken a glance at the progress of physical inquiry in the past, from the crudest fancies of the savage to the highly abstract conceptions of Newton and Laplace. And we have learned from this that the history of physical astronomy is a recital of the general belief in some conception of the mechanism of the heavens, the more careful examination of this conception after a time proving it to be erroneous, and its consequent rejection and replacement by a new conception, in turn generally received, in turn eventually rejected like its predecessor, and in turn replaced by still another conception. The last of this series of conceptions, is that of Newton as modified by Laplace; and acting in accordance with precedent we have sought to examine this conception also much in the same manner that each of its predecessors has been examined. Commencing with the most general conception of the nebular hypothesis we carefully considered the phenomena of nebular rotation, translation, contraction, subdivision, and development into the form in which the Solar, or the Sidereal System now exists; and we invariably found that each of these phenomena is wholly inexplicable by the received theory. A few specially important phenomena of our planet, such as the Moon's motion around it, the distribution of the Sun's heat both upon different portions of its surface and at its various distances from the Sun, and the phenomena of the tides upon its ocean surface —were then examined in the same manner; and in each of these instances the current theory appeared to be diametrically at variance with the actual facts.

Having previously broached a new theory and supported it with evidences furnished by the hitherto unexplained phenomena of the zodiacal light, the solar corona, the sunspots, and the connection of these with the phenomena of atmospheric pressure, precipitation, and electricity upon our own world, we now proceeded to examine, in connection with this new theory, the phenomena in which the current theory had failed; and these, without exception, were observed to corroborate the new theory in a wonderfully clear and simple manner. The remaining principal phenomena of the Sidereal System were then investigated, and in every instance the evidence obtained was plainly and strongly confirmatory of the evidence already adduced. The Saturnian Ring, the comets, with their various peculiarities of form and motion, the meteorites, which have been observed to fall upon the Earth out of the heavens, and which bring with them indubitable evidences of the processes of their origin—all have been, and still are, remarkably clear and direct witnesses in support of the connective theory. The hitherto silent and mysterious movements of the magnetic needle, manifested in its diurnal, annual, irregular, and secular variations, have for the first time found a voice apparently as true to this theory as the needle to the pole. Even the testimony of the rocks, the Coal Measures, and the great Ice Age, which time has engraved upon the Earth-crust, and which has heretofore remained undecipherable, is clearly interpreted by means of the guiding principle which this theory furnishes; and, in turn, further ellucidates and exemplifies it. And when we ascend to the remotest bodies of the Sidereal System, the new, the variable, and the periodical stars, and the various nebular forms, the light which they shed from the almost infinite depths of space, but illustrates the harmony of the theory with their various manifestations.

Thus, while the old Force-theory seems to be squarely confuted by several very important phenomena, and is incompatible with, or at least unrecognized by, many of the rest, every phenomenon of nature, without exception, appears to be consonant, and of a piece, with the new connective system here advanced.

185. *Conclusion.*—But a word of caution may not here be amiss. Although apparently so excellent and so agreeable with the facts, it can hardly be expected

that the new theory is perfect. Even though it may be regarded so meritorious as to be generally accepted in preference to any other, there are many considerations which lead to the belief that it *must* contain errors, and that it *may* be just as erroneous in comparison with a still more radical and exhaustive theory as its predecessor is in comparison with it. We apparently have no right at the present time to assume that we have attained to perfection in anything; and especially is this true in the case now under consideration of which past records show but successive acceptance of errors, each of which is only less gross than its predecessors.

But though we cannot yet claim perfect conception of the mechanism of natural phenomena, our duty now, as in the past, is none the less to cleave to those conceptions of them which appear to be the nearest to perfection, and willingly to reject all others. Whether we may or may not ultimately arrive at absolutely perfect conceptions of these things, we seem at the present time to have not sufficient grounds for deciding; but if ever we shall attain to such perfection, the ready acceptance of the less erroneous conceptions, however great the genius or the prestige by which opposing conceptions may have been maintained, is the only road which leadeth in that direction.

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AUG [illegible] 1931